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INTERNET-BASED PUBLIC PARTICIPATION GIS IN ENVIRONMENTAL MANAGEMENT

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By

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Environmental problems are among the most urgent and significant issues in contemporary society and have attracted increasing attention all around the world. How to deal with the interaction between human and natural environment and achieve sustainable development is the task of environmental management. With the development of the democratic process, participatory management and planning show incomparable advantages in the decision making process. How to facilitate public participation in environmental management is the research endeavor of this thesis. With the development of the Internet and technology, Internet-based PPGIS becomes an affordable and accessible GIS tool for public engagement. This thesis uses case study methodology, focusing on six current computer applications using the PPGIS tool in the environmental management field (Abandoned Developments, CoCoRaHS, eBird, OakMapper, OpenStreetMap, and What's Invasive!) to evaluate the current conditions. Through the SWOT analysis, a structured planning method to evaluate a project, the Strengths, Weaknesses, Opportunities, and Threats of the current use are studied. Although weaknesses and threats like the data quality issue do exist, the strengths and opportunities support the encouragement of this tool not only in environmental management issues but also in other social issues need general public participation in a wider range of time and

space. This thesis use the environmental justice issue as an example to provide suggestions based on the analysis results for the future better use of this tool in environmental management field.

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Last but not the least, I would like to express my thanks to my family and my friends, for their encouragement and support during my study.

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LIST OF ABBREVIATIONS

CENS	Center for Embedded Networked Sensing
CLO	Cornell Lab of Ornithology
COPPA	Children's Online Privacy Protection Act
EDDMapS	Early Detection & Distribution Mapping System
ENGO	Environmental Non-Governmental Organization
EPA	Environmental Protection Agency
GIS	Geographic Information System
GPS	Global Positioning System
JOSM	Java OpenStreetMap Editor
NGO	Non-Governmental Organization
PC	Personal Computer
PPGIS	Public Participation Geographic Information System
SOD	Sudden Oak Death
TQEM	Total Quality Environmental Management
USDA	United States Department of Agriculture
VGI	Volunteered Geographic Information

I. INTRODUCTION

1.1 Research Background

Environmental management, the means of controlling or guiding human-environment interaction to achieve a win-win situation for both humans and the environment (Randolph 2004), according to Wilson and Bryant (1997), is a "multi-layered process". Wilson and Bryant stated that the "layers" are divided by the different environments and primarily by the different groups of environmental managers. Environmental managers can be state environmental managers and non-state environmental managers, which includes non-state organizations like the environmental non-governmental organizations (ENGOs), international financial institutions, and local-level environmental managers like farmers, fishers, and hunter-gatherers. Who plays a more important role in environmental management? The "local versus global" issue has been debated for more than three decades (Clark 1989; Ehrlich and Ehrlich 1990; International Chamber of Commerce 1990; Agarwal and Narain 1992; Swift 1993; Chatterjee and Finger 1994; Pretty 1995). Recently, many researchers are inclined to solve the environmental problems by facilitating the communication and cooperation between the public and scientists, or say between the non-state and state environmental managers (Kusel et al. 1996; Mason and Dragicevic 2006; Lynam et al. 2007; Ban, Picard, and Vincent 2008; Fernandez-Gimenez, Ballard, and Sturtevant 2008; Jacobson et al. 2009; Devictor, Whittaker, and Beltrame 2010; Boulos et al. 2011). Since environmental management covers a huge range of values, like scientific and economic determinations as well as issues of social equity and environmental ethics, the decision-making process should be

participatory (Randolph 2004). Wondolleck and Yaffee (2000) concluded four advantages brought from collaborative planning, according to the previous failures that didn't effectively engage public skateholders: information sharing and understanding building, wise decision making and support building, responsibility building, and social capital enhancing. While our society is rapidly moving towards digital, with the development of Social Web (Web 2.0) and the pervasiveness of the personal computer (PC) and mobile devices, such as smart phones and tablets, the Internet-based communication platform provides a critical channel for public participation, and integrated geographic information system (GIS) technology allows the partcipation in spatial-related issues. This study will focus on using Internet-based public participation geographic information system (PPGIS) technology to help grassroots power get involved in environmental management.

1.1.1 The importance of public engagement

As stated before, public participation is a vital part of planning. It is not only dealing with deliberate hearings, but also seeking and facilitating public involvement in planning topics and the decision making process (Goodspeed 2008). Effective participation is a two-way process that includes sending information out to publics and getting their ideas, concerns and thoughts back (Godschal et al. 1994). According to Brody, Godschalk, and Burby's article (2003), "citizen participation is widely viewed as a key component in the planning process, and for the most part, planners accept the notion that participation is important to producing enduring plans." Brady and Long (1972) also pointed out that public participation plays an important role in the urban planning process as adult

educators. As public servants, it's crucial for urban planners to understand citizens' interests and to provide better living environment for them.

Some scholars conducted research on analyzing the levels of public participation. Godschal and his colleagues (1994) introduced guidelines for the level of involvement in "A Planning and Development Consensus Building Manual" which argued that people are involved in different levels because they perceive threats or benefits to the economy, institution, and personal interests differently. If people have strong interests or benefit, they are more likely to try to influence the decision making process which can lead to high involvement. It's a major issue for urban planners to spread effective information to facilitate the level of public involvement because publics play an important role in urban planning processes. Public participation and collaboration can resolve the conflicts to a certain extent, develop a shared vision among public, professionals, and governments; and the ultimate goal of public engagement is to formulate creative solutions beyond the traditional planning outcomes, based on collaborative efforts (Randolph 2004).

1.1.2 Facilitate collaboration and participation

Two significant components in collaborative environmental planning are framework and stakeholder involvement, and the latter is "the heart of collaboration" (Randolph 2004). Wondolleck and Yaffee (2000) provide some useful suggestions to facilitate collaboration: build a common ground, create effective and enduring interactions, use new ways to solve problem, foster the sense of responsibility, focus on individuals, and practice an entrepreneurial approach. Based on this guideline, Randolph and Bauer (1999) concluded six basic tasks in stakeholder involvement: indentify stakeholders, establish authority, structure the process, achieve trust, share authority, and assign roles,

and the main goal is to engage in collaborative learning. According to Randolph and Bauer, the greatest challenge is achieving trust among participants with different interests. Also, other barriers confronting collaborative environmental management include: missing information, conflicting interests and goals, lack of time, lack of responsibility, and lack of expertise. What is more, there are some obstacles that challenge the public participation process: missing identification of stakeholders, inaccessible time and place, techinical and language barriers, historical biases, issues that are too complex, and long decision time.

1.1.3 Tools for collaboration and participation

Technique	Description	Advantages	Disadvantages
Media	Press release; TV, radio, newspaper	Informing information	No communication
Public meetings/hearings	People present official statements and assertions of fact	Anyone could join and contribute	Citizens rarely engage in and opinions cannot be extensive
Workshop	Public convened with a specific urban planning plan, expressing opinions through exercises or games	More interactive and two-way communication	Limited participators
Polls and Survey	Identify concerns and interests of public via mail, email, website, etc.	Can collect different opinions from large and diverse population	Costly, low responds
Focus group	Generate understanding of public opinions from a small group of people	Help planners send information and get feedback immediately	Limitation on numbers of gathered citizens
Electronic Networks	Use Internet to informing and get people involved	Low cost, reach more people	Not everyone has the device to access to Internet.
Interview	Private conversation in person or via telephone	Can get citizen's deep thoughts	Time and money consuming

Table 1-1 Pros and Cons of Public Participation Techniques

Traditional techniques to facilitate public participation in environmental management are similar as those to facilitate public participation in urban planning process – such as media, public meetings or hearing, workshops, polls and surveys, focus groups, electronic

networks, and interviews (Godschal et al. 1994, Randolph 2004). Table 1-1 shows the pros and cons of traditional public participation techniques.

This thesis chooses Internet-based PPGIS as the tool to facilitate public engagement in environmental management. The term Internet-based PPGIS is more like a comprehensive concept than an unambiguous definition. It is the combination of web-based GIS, PPGIS, volunteered geographic information (VGI), and integrated with social media, to address a specific issue (Figure 1-1). For the term web-based GIS, it is like a technological definition to describe the potential of this rising tool. First, through the internet-based GIS, everyone can publish and access spatial data. What's more, internet-based GIS can be used to create interactive maps to facilitate the communication between different groups – for example, specialists like planners can communicate with the general public, especially those who have lower socioeconomic status. Third, web-based GIS can provide basic GIS functions (for instance, pan, zoom, and query attribute data) with browsers (Drummond and French, 2008). For the term PPGIS, the name is more issue-driven. The objective of the tool is very clear – facilitate public participation. According to Weiner, Harris, and Craig (2002), PPGIS is a system that mainly addresses the local

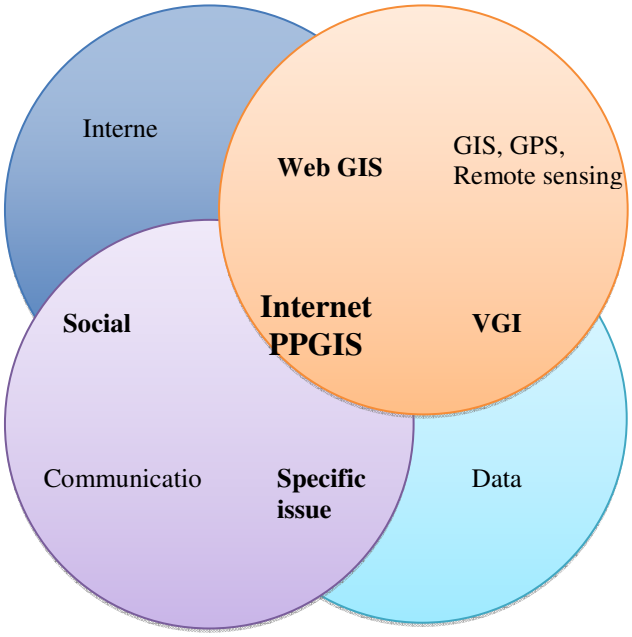

Figure 1-1 Framework of Internet PPGIS

level and can be used in many socioeconomic contexts. Another important function of PPGIS is to gather both qualitative and quantitative information. The reason why PPGIS has developed in recent years is largely due to some groups (especially disadvantaged groups) of people who cannot access conventional GIS and therefore stay in a passive location of the decision-making process. The development of PPGIS paves the way for ordinary people and nongovernment organizations (NGOs) to access GIS to influence public policy. For this reason, PPGIS is a significant research area in geographic information science. Both Internet-based GIS and PPGIS are cost and time saving, easy-to-use, efficient, accurate, and productive. They provide enhanced communication and collaboration, more efficient allocation of resources, and improved access to timely data and information (Sieber 2006; Drummond and French 2008; Thomas and Sappington 2009). The integration of Internet-based GIS with PPGIS to enhance public participation in planning processes is one aspect of future trends of the GIS development (Weiner, Harris, and Craig 2002; Drummond and French 2008). VGI represents a new data collection method – user generateed data (Goodchild 2007). Social media, such as Facebook, MySpace, Twitter, and YouTube allow individuals to become part of the larger political process through their personal digital products. Because online social networking and virtual reality tools allow information to be spread more quickly, it is possible to grow groups to thousands instead of holding a planning meeting for a few dozen people (Owyang 2008). Marring PPGIS with the Internet platform and using citizens as sensors (Goodchild 2007), along with the help of social media, people can be encouraged to participate effectively in the environmental management policy-making

process. Table 1-2 shows some obstacles in collaborative environmental management and how Internet-based PPGIS can effectively respond to these challenges.

Barriers to collaborative environmental management	Potentials of Internet-based PPGIS
Missing information	Ubiquitous and timely data and information
Conflicting interests and goals	Provide a platform for communication
Missing identification of stakeholders	Everybody can participate
Inaccessible time and place	Time and place are flexible
Technical barrier	Easy-to-use compare with traditional GIS

Table 1-2 Potentials of Internet-Based PPGIS to Solve the Collaborative Environmental Management Barriers

Internet-based PPGIS tools cannot directly get rid of other barriers to collaborative environmental management like language barrier, lack of responsibility, lack of expertise, historical biases, issues that are too complex and long decision time. For instance, to promote greater accountability, evaluation procedures can be added in the process; and a project should address a relatively small topic with clear target to reduce complexity and time. These barriers should be considered in designing a project to take advantage of Internet-based PPGIS tools: for example, if a project contains a certain number of non-English-speaking stakeholders, the interface may need to support other languages or use simple symbols to illustrate or provide education/training programs for them.

1.2 Thesis Overview

This thesis addresses a number of important research topics in taking advantage of the Internet-based PPGIS to involve large number of stakeholders, especially the general public, to engage in environmental management. The potential of Internet-based PPGIS as an effective and friendly platform for data submission and demonstration will be discussed. This thesis includes case studies for some successful Internet-based PPGIS environmental platforms to discuss the strengths, weaknesses, opportunities, and threats

of the current use. After analysis, suggestions will be provided for making better use of Internet-based PPGIS in environmental management, specifically for use of this tool to promote environmental justice. Research objectives of this thesis are listed below:

- Understand current use of Internet-based PPGIS in the environmental management field;
- Identify the strengths, weaknesses, opportunities, and threats of the current use of Internet-based PPGIS in the environmental management field;
- Provide suggestions for future use of Internet-based PPGIS in the environmental management field based on keeping strengths, improving weaknesses, responding to threats, and seizing opportunities.

This thesis contains six chapters to answer these questions and achieve these objectives. Chapter one is the introduction, statement of the background, and an overview of this research. Chapter two includes literature review, a review of the history and objectives of environmental management and Internet-based PPGIS, respectively. Chapter three focuses on the methodology, including discussion of a conceptual framework, choosing the criteria for analysis, selecting target cases, and analyzing cases. Chapter four is the results, using SWOT analysis to analyze the strengths, weaknesses, opportunities, and threats of the chapter three outcomes. Chapter five is discussion, mainly focusing on the possibilities to use of Internet-based PPGIS in environmental management. This chapter also discusses the issue of environmental justice in relation to Internet-based PPGIS. Chapter six presents conclusions from this research, and points out the limitations and possible future works.

II. LITERATURE REVIEW

This study separately reviews literature on environmental management and Internet-based PPGIS, specifically their history and objectives. Through the literature review, the origin and development of environmental management and Internet-based PPGIS can be understood, as well as what problems they addressed and tried to solve. The literature review will achieve a help better understanding of the objectives of this study.

2.1 History and Objectives of Environmental Management

Environmental management emerged in the academic world with the launch of The *Journal of Environmental Management* in the United Kindom in 1973 (Jeffers 1973). Three years later, in United States a journal entitled *Environmental Management* was established to discuss the scientific and policy-making issues in this field (DeSanto 1976; Sandhu 1977; Alexander 1985). According to Wilson and Bryant (1997), the biggest challenge faced by environmental management is uncertainty. This uncertainty reflects on the environmental, sociocultural, political, and financial dimensions; and each group of environmental manager faces different uncertainty. To solve this problem, environmental management has to to address predictability. In recent years, human-environmental interaction has been intensified due to the large number of population growth and the extreme transformation of natural environmental to built environment. The intensified human-environmental interactions increased the uncertainty of environmental management. Other influencing factors include the financial one and political one. With the increase of population, the amount of non-renewable natural resources remains in a certain level, and the amount will decrease with the increase of

population, and the growth rate of renewable resources cannot be comparable with the growth rate of population. Therefore, there is a question of how to distribute limited resources among the continually increasing population. This is an urgent problem for environmental management. Moreover, both the amount and the type of environmental managers have been increased; that means more people should be involved in the environmental management decision-making process. Besides this environmental uncertainty, Wilson and Bryant also mention the social uncertainty – based on environmental managers' differing attitudes and worldviews. However, people with conservationist attitudes and ecocentric worldviews and people with utilitarian attitudes and technocentric worldviews have to coexist in the world. How to mediate contradictions to achieve a compromise is also an important task for environmental management. Wilson and Bryant discussed the potential of politics, market, and policies to enhance the predictability of environmental management to combat the uncertainty. Political and financial processes are not neutral processes. These processes will put some groups of environmental managers to a disadvantage. They solve problems as well as bring new ones. Policies are used to overcome these differences. However, enhanced predictability for some often means added uncertainty for others; a consensus embracing all environmental managers may never been reached. Fortunately, environmental management researchers always keep studying on different areas to pursue a common goal – sustainable environmental management.

In recent years, environmental management research has addessed such topics as sociocultural factors (Satterfield et al. 2013), local collaboration (Hindmarsh 2012; Kubacka 2012), and policy support (Zhu, Cordeiro, and Sarkis 2013). Satterfield and her

colleagues (2013) have studied on how cultural factors will influence environmental management. They examined three cases in which environmental decision making has heavily relied on local culture: risk management of genetically modified organisms with Maori concerns in New Zealand, marine planning with the cultural services in coastal British Columbia, and a decision making process about water flows in a regulated river with the participation of a local First Nation in western Canada. The conclusion of their research is that, even if the benefits of cultural influencing factors are not obvious when cultural factors contradict the efforts to quantify benefits, communication and consultation with community members can help to improve the situation. Hindmarsh (2012) takes advantage of "place-change planning" to facilitate all stakeholders', especially the important but most neglected community stakeholders' ability and encourage them to participate in water management. Kubacka's (2012) research is about local cooperation of communities and other organizations to solve the contradiction between ecosystem and economy in Potland. Zhu, Cordeiro, and Sarkis (2013) study the impact of domestic and international institutional pressures. They try to find out whether these pressures can lead to the successful implementation of environmental management systems or Total Quality Environmental Management (TQEM) systems. Their research results confirmed the hypothsis – institutional pressures can lead to the environmental management success. And they suggest developing countries to support the implementation of ISO 9000, a quality management system to deal with environmental management issues by local firms.

Cooperation among different groups of environmental managers and seek of policy support are the maintream of contemporary environmental management, as well as the

marketing process. Cavalcanti, Engel, and Leibbrandt (2013) studied the relationship between individual social integration and participation for cooperation. The research results show the fishermen, as the participate in the environmental program, who are more integrated into the community's social network are more cooperate in the program. Also, their findings support the idea that clearly understanding a program can facilitate participation. Bretschger and Smulders's (2012) research is about resource markets and sustainable resource use policies. Fischer and Fox (2012) study anti-leakage policies to greenhouse gas emissions. Four policies have been analyzed: a border charge on imports, a border rebate for exports, full border adjustment, and domestic output-based rebating. The analysis results show each policy has pros and cons. Acuff and Kaffine (2013) study on the least-cost policies for waste reduction, recycling, and grennhouse gas emissions. Marketing researches on environmental management also including the comparison of soft and hard price collars in a cap-and-trade system (Fell et al. 2012) and market power in water markets (Ansink and Houba 2012) in recent years.

2.2 History and Objectives of Internet-based PPGIS

With the development of Geographic Information System (GIS), it's not only just a tool but also like a "social process" (Sheppard 1995). This judgment helps to understand the significance of the relationship between GIS and society. As in an old saying, "a picture is worth more than a thousand words", spatial graphics plays a vital role in public policy making. With the development of technologies, including Internet-based mapping tools, customer terminal equipment such as the personal computer and smart phone, and Global Positioning System (GPS), a new kind of GIS – Internet-based public participation GIS

has been used to solve spatial and social problems. The reason why PPGIS is developed in recent years is largely due to some groups (especially the disadvantaged group) of people cannot access the conventional GIS and stay in a passive location of the decision-making process. The development of PPGIS paves the way for ordinary people and nongovernment organizations (NGOs) to access GIS to influence public policy. This is the current trend of GIS development. For this reason, PPGIS is a significant research area in geographic information science. More over, marry PPGIS with Internet platform can maximize the effectiveness of encouraging people participate in policy making. Thomas and Sappington (2009) pointed out that GIS can support and contribute to public policy making because it has advantages such as cost and time saving, increased efficiency, accuracy, and productivity, enhanced communication and collaboration, more efficient allocation of resources, and improved access to information. These characteristics are even more marked in internet-based PPGIS.

Some previous researches showed the use of Web PPGIS. Casey and Pederson (2002) did a project incorporates local community knowledge of historically marginalized neighborhoods by internet-based 'public records GIS'. Build local capacity for neighborhood improvement in City of Philadelphia. Carver et al. (2002) designed a web based public participation 'planning for real' system. This project illustrated the potential of using web GIS for facilitating public participation in environmental decision making. Internet PPGIS also can be used in the land use planning. Ventura et al. (2002) developed a land information system including web-based tools like chat rooms and electronic town hall meeting to support the land use planning. A visualization project at University of

Illinois took advantage of web-based survey to collect public preferences for neighborhood design (Al-Kodmany 2002).

Moreover, Internet-based PPGIS could be used in the environmental and public health surveillance and crisis/disaster informatics (Boulos et al. 2011). Through the review of Sensor Web, citizen sensing and "human-in-the-loop sensing", they found the horizontal communication among volunteer citizens has advantages such as more timely and complete. In environmental and public health field, this kind of horizontal-communication-support technology plays a vital role in "crowdreaching" besides the "crowdsourcing". Heath tips like pre-operatory or post-operatory guidelines, pregnancy FAQ, or recipe for diabetes could be provided to public. Devictor, Whittaker and Beltrame's (2010) study is about the possibility of using citizen science to improve conservation biogeographic studies. They analyzed three major aspects of the currently running citizen science programmeds: scale (including spatial scale, temporal scale, and sample size), ecological characteristics (including specific target, taxonomic groups, and ecological level), and requirements of partcipators (including skill, time requried, education, and communcation). Their results show the citizen science is particularly useful in solving problems in large temporal and spatial extents. Citizen science programs should be encouraged since it is not only valuable for conservation biogeography, but also can strengthen the connection between people and natural environment and between people and science.

III. METHODOLOGY

This chapter describes how to select cases and how to analyze them to understand the current use of Internet-based PPGIS in the environmental management field. A conceptual model is provided to guide the selection of analysis criteria, and the case selection is based on qualitative analysis guidelines (Gaber and Gaber 2007) and case study methodology (Yin 1994; Rowley 2002).

3.1 Conceptual Framework

To summarize the relationship between Internet-based PPGIS and environmental management issues, and to analyze and compare selected cases, a conceptual model (Figure 3-1), modified from previous research, has been established in this thesis. This model is based on MacEachren's (1994) characterization model for cartography, Dragicevic and Balram's (2006) "collaborative GIS cube", and Connors, Lei and Kelly's (2012) conceptual framework of the intersection between volunteered geographic information, citizen science, and environmental monitoring. MacEachren's model mainly focuses on visualization, tries to transfer the use of maps from private visual thinking to public

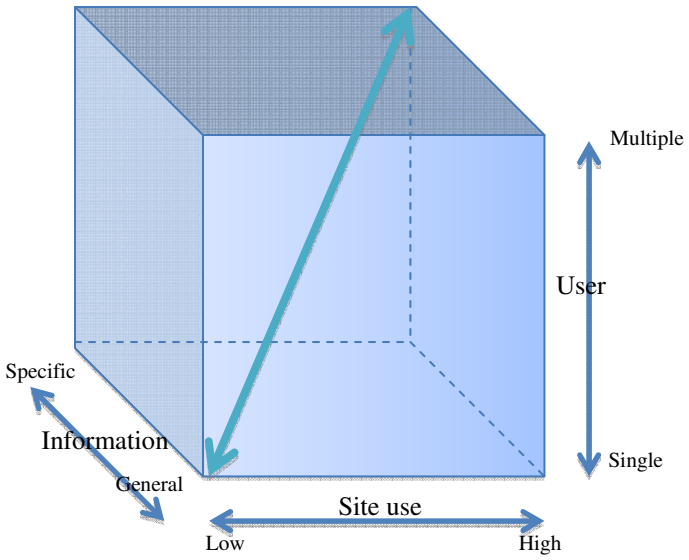

Figure 3-1 Conceptual Model

visual communication. His model uses three variations – map use from private to public, map use for revealing unknowns versus presenting something we already know about, and human-map interaction from high to low, to determine a map is used for visualization or communication. According to MacEachren's model, a map for public to reveal unknowns, with high human-map interaction, is something like SimCity can allow participators to influence public policies. However, in MacEachren's age, this kind of mapping still remains in simulations. Collaborative GIS cube uses participation, map usage, and technology as variables to evaluate the trends in planning and decision making. When participation reach to a certain level, that means involve a certain number of public, and the map usage is the highest, planning and decision making can be an argumentative turn, a collaborative turn, and a distributive turn with the development of technology – from non-digital, local area network, to Internet/wireless. And when all three criteria, the public involvement, map usage, and technology reach to the maximum value in this model, it is the collective team – large number of participants equipped with Internet/wireless technology to make their contribution to the decision-making process. Users, information, and interaction are the three variables of Connors, Lei and Kelly's model. They use this model to testify whether their OakMapper interactive site is a project with high specificity in collected data and high intentionality and interaction between database and users. To build the model for this study, firstly, the relationship between environmental management and the variables selected in the conceptual model. A diagram (Figure 3-2) has been used to illustrate this relationship, and the connection is the public participation. To facilitate the public engagement in environmental management, three significant points should be noticed.

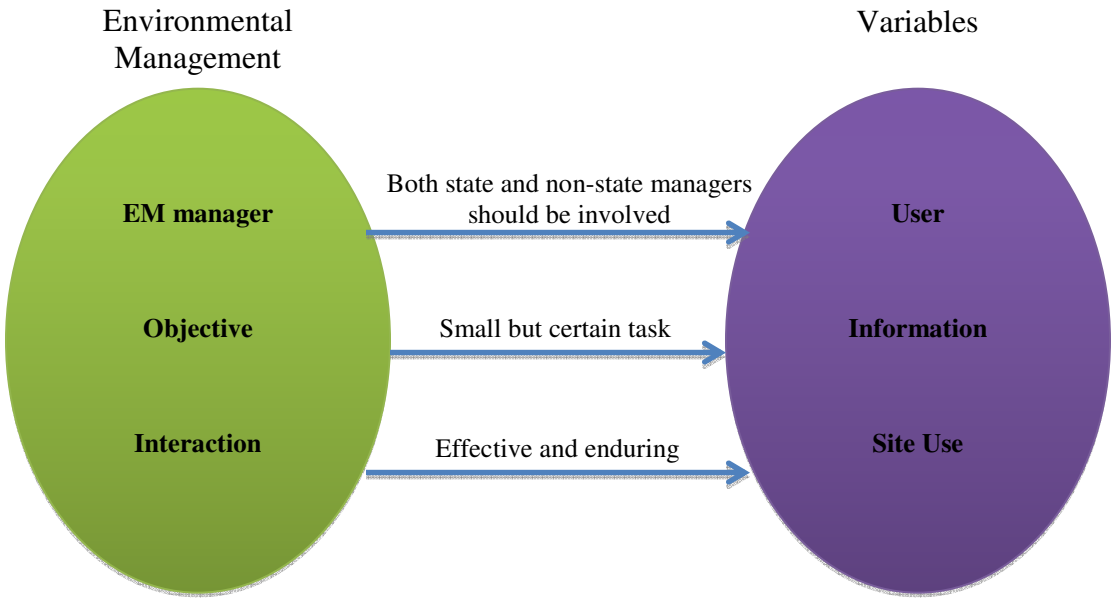

Figure 3-2 Relationship between EM and the Model

First is the environmental manager. As stated before, environmental manager can be state manager like governmental organizations and non-state manager like ENGOs or individuals. For the concept of participatory environmental management, both state and non-state managers should be involved in the environmental management process. Second is the objective. How to retain long-term and active participators is a big problem environmental management faced. One solution is to complete the small but certain task in the first place, when groups achieve success in a short term, they may have confidence and ability to solve other more complex issues. Third is the interaction. Create effective and enduring interactions is another way to facilitate collaboration. In this case, the interaction is not only between users and the site, but also between general public users and professional users. Therefore, user, information, and site use are the three variables in this model. Users vary from single group to multiple groups including public users, information from general to specific, and site use from low to high. This model indicates

an ideal condition of an Internet-based PPGIS site to facilitate the public engagement in environmental management: involve both state and non-state environmental managers as users to solve a small but certain task with high interactions. This conceptual model will be used to evaluate the target cases, both on their design objective and their service condition, to know how well they work on the environmental issues in terms of getting people involved.

3.2 Criteria for Analysis

In this section, detailed criteria for analysis will be identified based on the concpetual model. As mentioned before, this model uses user, information, and site use to evaluate a target's performance. Therefore, the detailed criteria are under these three broad headings. For the first category, user, there are two aspects need to be analyzed – group and number. This study tries to figure out which groups are participators in this project: state or non-state environmental manager, specialists or general public. Also, participator' backgrounds is important to this study too, for instance, their age, gender, education level, etc. Moreover, the number of the participators should be analyzed: the total number of participator who scan/contribute to/get information from project Website and the number in each period. For the second category, information, this study tries to figure out what objective the project has, and why choose Internet-PPGIS to solve this problems, and how to solve it. Last, for the category of site use, the number of participator will be anaylzed in this part too as a reference to evaluate the interaction level. In the meantime, this study will find out what kinds of interaction in each cases, both online and offline.

All of the analysis will be in two conditions – the designed one and the practical one, except the objective. Table 3-1 shows the detailed criteria under the three categories.

	User		**Information**		**Site use**
	Group	Number	Objective	Data	Interaction
Design Goals	Target user	Estimated user number	Issue and why choose Web PPGIS	What kinds of data plan to collected	Communition platform provided
	Target user background		How to solve the problem		
Practical Situation	Actual user	Actual user number	Problems be solved or not	What kinds of data actually collected	Service condition of communication platform
	Actual user background				

Table 3-1 Detailed Criteria for Analysis

3.3 Target Cases Selection

This paper uses case studies as the major methodology. Through the qualitative analysis, find out what current PPGIS doing with environmental issues, analyze how well they did, summarize their experiences and advantages, notice the shortcomings, and provide practical advices on how to use Internet-based PPGIS to promote environmental management. The scope of target projects in this study is based on the pervious researches on the web GIS in North America and Europe (Wald et al. 1999; Kearns, Kelly, and Tuxen 2003; Karns et al. 2006; Cifelli et al. 2005; Haklay and Weber 2008; Sullivan et al. 2009; Devictor, Whittaker, and Beltrame 2010; Evans-Cowley and Hollander 2010; Goodchild and Glennon 2010; Haklay 2010; Berry et al. 2011; Boulos et

al. 2011; Connors, Lei, and Kelly 2011; Genskow and Wood 2011; Gollan et al. 2012; Jordan et al. 2012; Lanthrop et al. 2012; Werts et al. 2012). According to the research about case study (Yin 1994; Rowley 2002), case study design should address the objectives of the study, and the case selection should be in accordance with the topic. Since this study addresses the Internet-based PPGIS and environmental management, the two primary requirements to choose targets are using web GIS as interactive platform to collect and demonstrate spatial information and attract people participate, and address environmental issues. Also, data collection and presentation, founder and coverage area have been considered as the filter criteria (Table 3-2). Platform requires selected cases should use Internet-based PPGIS as tools; issue of selected cases should be related to environmental problems since this study focuses on environmental management; data collection requires selected cases use public-submitted data as their primary data source; data presentation requires cases should provide the data and research and statistic results to general public, data collection and presentation are the objectives of Internet-based PPGIS; founder and coverage criteria are used to avoid the repeatability and ensure the diversity of selected cases. Six mainstream projects have been selected and will be analyzed in this study: *Abandoned Developments* (www.adandoneddevelopments.com), *CoCoRaHS* (www.cocorahs.org), *eBird* (www.ebird.org), *OakMapper* (www.oakmapper.org), *OpenStreetMap* (www.openstreetmap.org), and *What's Invasive!* (www.whatsinvasive.com). Table 3-3 shows all the six projects meet the requirements.

Criteria	Significance	Description
Platform	Required	Web-based interface.
Issue	Required	Relate to environmental problems.
Data collection	Required	Data collected by general public/volunteers.
Data presentation	Required	Public can easily access collected data.
Founder	Referential	Avoid projects from the same founder.
Coverage	Referential	Each project covers different study area would be better.

Table 3-2 Criteria for Case Selection

	Platform	Issue	Data collection	Data presentation	Founder	Coverage area
Abandoned Developments	Silverlight map application	Abandoned residential construction sites	Volunteer submit	Original study and submittals can be viewed through Sliver light Viewer.	Clemson University, 2011	Southeaste rn United States.
CoCoRaHS	Interactive Web-site	Precipitation	Volunteer s submit	"Quick" or detailed" precipitation observation	Colorado Climate Center at Colorado State University, 1998.	United States and Canada
eBird	Web-interface.	Bird	By recreation al and professio nal bird watchers.	Provide real-time, online checklist, visualize data with interactive maps, graphs, and bar charts.	Cornell Lab of Ornithology and National Audubon Society, 2002.	Western hemispher e and beyond.
OakMapper	Web GIS, interactive map, integrated with social media.	Sudden oak death (SOD)	VGI	Distributing spatial information of SOD.	UC Berkeley, 2001.	California State.
OpenStreetMap	Web-based interface, use Potlatch and Java OpenStreetMap Editor as editing tools.	Built environment: streets.	Volunteer submit.	Free download, and immediately useful forms.	University College London, 2004. The OpenStreetMap Foundation.	Around the globe.
What's Invasive!	Smart phone application and Web site.	Invasive species	Volunteer submit	Showing on the map, and data can be downloaded.	The CENS at UCLA, the Santa Monica Mountains National Recreation Area, and EDDMaps, 2006.	110 parks in United States.

Table 3-3 Selected Cases

3.4 Analysis

Six cases have been selected, issue from natural environment to built environment, coverage from State to all around the world, and all the cases use Internet-based PPGIS to collect and demonstrate data. To understand their current work, this study uses criteria (Table 3-1) based on the conceptual model to analyze these six cases. In this section, firstly, the background of each case will be described, then the current condition of user (including user number and background), information (including what objectives each case has and what data it collects), and site use (primarily the interaction of each case, what communication platform it uses) will be demonstrated. These kinds of information provide a general understanding of the current condition of each case.

3.4.1 Background of cases

Abandoned Developments

Abandoned Developments is a project that tries to identify the water quality issue in abandoned residential construction sites because the soil on unfinished sites may erode into streams and lakes then cause pollution. It is designed and supported by Clemson University that provide an interactive map allow residents upload geographic data and photos of those places in South Carolina, available in February 2011. The Web-mapping interface integrates Microsoft Silverlight (require users installed before use the interactive map), Bing Maps, ArcGIS Server, Google Picasa Web Albums Data API, RSS, Google Analytics, and Facebook (Werts et al. 2012). The interactive map shows the sample of the original study that allow public to view, and people can view and comment on other users' submissions besides they contribute their own.

CoCoRaHS

According to the definition from the official website cocorahs.org, *CoCoRaHS*, The *Community Collaborative Rain, Hail and Snow Network*, is a non-profit, community based, high density network of volunteers who take daily measurements of rain, hail and snow in their backyards. This project includes local citizens in precipitation monitoring to increase their awareness while also providing timely data for decision makers. *CoCoRaHS* was founded in Fort Collins, Colorado in 1998, and supported by local funding. With the increasing number of volunteers and funding, *CoCoRaHS* became a nationwide volunteer network in 2010. It provides educational program and training sessions like seminars by local scientists and field trips to nearby weather research facilities for volunteers. These are welcomed among volunteers and become a means of engaging, motivating and retaining volunteers. Volunteers can submit either a "quick" or a "detailed" precipitation observation report on the Web site.

eBird

eBird takes the advantage of new information technologies to engage a huge network of recreational and professional birders to report bird observations by suing standardized protocol to a centralized database. It is a citizen science project launched by the Cornell Lab of Ornithology (CLO) and the National Audubon Society in 2002 (Sullivan et al, 2009). Because public can largely contribute to the understanding of bird identification, distribution, and abundance (Barrow 1998), *eBird* tries to harness the power of public observation to understand birds better both for general public and scientific purpose. Anyone in anywhere at anytime, participators can simply submit their observation data via Internet or through a variety of handheld devices. According to Sullivan et al. (2009),

the data collected by *eBird* will be used in several scientific aspects: first, it provides a valuable resource for visualizing seasonal distribution changes; second, the data can help monitoring avian range changes; third, *eBird* data can be used to examine the timing of migration; fourth, it can be a tool for priority species conservation; fifth, delineating migration timing can be used for conservation management; sixth, *eBird* provides data resources for decision support tools; and seventh, modeling relative abundance.

OakMapper

According to Connors, Lei, and Kelly's (2012) study, OakMapper.org is a Web site for collecting and distributing spatial information related to the spread of a highly visible invasive forest disease – sudden oak death (SOD). *OakMapper* has two versions, version 1.0 and the update version 2.0. It's born to locate new areas of SOD infestation across California State. The first *OakMapper* Web site was created in 2001 and a Web GIS was developed to coordinate and distribute all SOD spatial data. However, *OakMapper 1.0* has some limitations: each element of the Web site (spatial data, mapped products, volunteered information) existed independently and required routine maintenance to remain up to date. These methods were not only time consuming but also susceptible to errors and inconsistencies between resources. *OakMapper 2.0* put the target users group, the means of interaction with the system, the data set to be supported, and the state-of-art for information and geospatial technologies in the first place in order to take advantage of VGI and the advancement in Web and GIS technologies. The new website considers the site's usability, integrability, and scalability, tries to increase data flow and to enhance producer experience by using new technologies. The *OakMapper* Web site is based on an interactive map, which serves as a portal to a single spatially enabled relational database.

Moreover, participation, a hallmark of Web 2.0, is realized on *OakMapper* as contributions of geospatial information and interaction with map-based content. Other services such as the location-based service for iPhone, Flickr, and Twitter were integrated with the Web site, provided alternate modes of participation to users, while taking full advantage of hardware, such as cameras and GPS devices that users have at their disposal.

OpenStreetMap

The *OpenStreetMap* is probably the most extensive and effective knowledge collective project that provides user-generated street maps, born at University College London (UCL) in 2004 and founded by Steve Coast. Its emergence announces that not only professionals can make maps, but ordinary people also can. *OpenStreetMap* followed the Wikipedia model: free to use, editable, and licensed under new copyright schemes. One of the editing tools of *OpenStreetMap* is Potlatch, a lightweight online Flash-based editor; it allows users add, update, or delete geographical features through a relatively easy-to-use interface. Experienced users will choose Java OpenStreetMap Editor (JOSM), which has an interface similar to traditional GIS packages. *OpenStreetMap* project combined the social and technical challenge. It allows ordinary people take part in the map-making process. But this project still has some limitations such as the fitness for purpose of *OpenStreetMap* data, the influence of geography and participation on the project, the ability to continue to update the information, and licensing.

What's Invasive!

What's Invasive! is a project that try to integrate with general public to locate invasive species anywhere in the United States by making geo-tagged observations and taking

photos to alert people of the spread of habitat-destroying invasive plants and animals. This project is held and supported by the Center for Embedded Networked Sensing (CENS) at the University of California, Los Angeles, the Santa Monica Mountains National Recreation Area, and EDDMapS, a web-based mapping system for documenting invasive species distribution developed by the University of Georgia – Center for invasive Species and Ecosystem Health. Individuals who have GPS-enabled Android smart phone or iPhone can easily download *What's Invasive!* application then contribute to the observation of invasive species. Also, people can simply log in the Web site and go to My Data page to create a new observation from their computer.

	Intention	**Technology**	**Other services**
Abandoned Developments	Identify the water quality issue in abandoned residential construction sites.	Microsoft Silverlight, Bing Maps, ArcGIS Server, Google Picasa Web Albums Data API, RSS, Google Analytics, and Facebook.	
CoCoRaHS	Take daily measurements of rain, hail and snow.	Interactive Website for data submitting and data presentating (interactive map).	Educational program and training sessions.
eBirds	Report bird observations by suing standardized protocol to a centralized database.	API	Data verification process
OakMapper	Collect and distribute spatial information related to the spread of SOD.	VGI, Web and GIS technologies, Google map.	Location-based service for iPhone, Flickr, and Twitter.
OpenStreetMap	Create and distribute free user-generated geographic data for the world.	Potlatch, and Java OpenStreetMap Editor.	Workshop
What's Invasive!	Locate invasive species anywhere in the United States	Application on GPS-enabled Android smart phone or iPhone.	Web page.

Table 3-4 Basic Information of Each Program

Table 3-4 concludes the intention of each program, as well as the technology used, and other services provided.

3.4.2 User

- User group

Abandoned Developments

According to the Children's Online Privacy Protection Act (COPPA), *Abandoned Developments* do not collect any information from anyone under 13 years of age. This project welcomes general public who are at least 13 years old or older to get involved. Since all data collection are completed online, and according to the project's privacy policy, this project only record users' email address when they submitting an abandoned development location on the Website. No other personal information will be asked in this project. Google Analytics is used for tracking anonymous site statistics like number of pageviews, site visits, length of time on site, time taken to complete a submittal, and time spent exploring subimttals. Therefore, there is no background data of users to be analyzed.

CoCoRaHS

According to the project's official public statement, *CoCoRaHS* is a community project and anyone can participate with no age strictions. The only requirement for participators is willing to learn about knowledge of weather and has long-lasting enthusiam to record and report weather conditions. Willing participator can simply sign up as a volunteer observer through "Join the *CoCoRaHS* Network" Web page. In this page, basic information about observer like name, phone number, email address, mailing address, station location information, age information will be recorded. Moreover, to become an

observer, rain gauge is a necessary tool. Rain gauge and other tools can be ordered from the online store (www.weatheryourway.com/cocorahs), price is from $0.5 (recording sheet) to $218 (ETGage). The official *CoCoRaHS* gauge costs 28 dollars. In the end of the application, participator can choose one training method they prefer – online training, attend a training session or walk-in training.

At the beginning of *CoCoRaHS*, three high school students were running this project. One worked for the map, one worked for the data, and the third one worked for the volunteer program. According to the official data, the age range of volunteered observers is from as young as preschool boys and girls to as old as 90. From establishment to design to recruit public volunteers, high school students play a vital role in this project.

eBird

According to the description of this project, generally, everybody, without considering of any background, can take part in *eBird*. But the long time and active contributors are those who like birds. *eBird* only ask for name and email address when create an account. Personal information including age, gender, education level, occupation, company, address, and phone number are optional to submit. However, based on the recommended citation from *eBird*, *eBird* primary reference (Sullivan et al. 2009) dose not release any background information about observers.

OakMapper

OakMapper has no particular requirement for users. When create an account to submit data, users need to state their background – academic, government, or public. This is the only background data *OakMapper* collected. Based on this, data shows *OakMapper* has

distinct user groups, including scientific researchers, agency officials who provide laboratory-confirmed cases, and the general public. And most audiences are assumed have no GIS experience before, but *OakMapper* also provides some advanced function for researchers and government agents, so its interactive site is designed for different user groups by creating permissions levels for individual accounts. Backgrounds of public participants are showed in Chart 3-1.

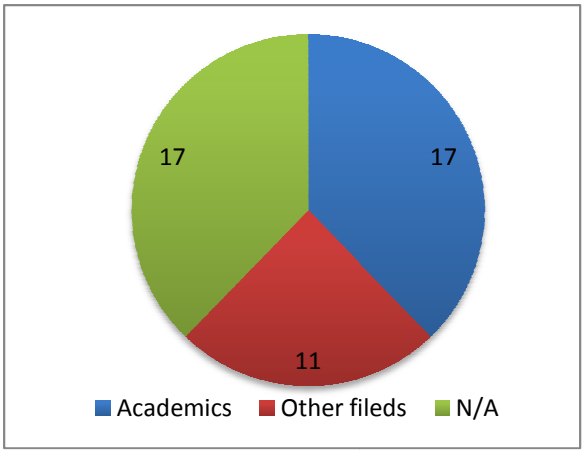

Chart 3-1 Background of OakMapper Public Participators

OpenStreetMap

No background requirement for *OpenStreetMap* contributors. Users even do not need use their real names and the email address is used for validation and communication. However, there are some technique requirements. The basic requirement is a computer connected to the Internet. And if users choose use GPS to collect data then they must have a GPS unit and connecting cable. *OpenStreetMap* dose not record any background information about users.

What's Invasive!

What's Invasive! users should be older than 13 years. When register as a user and participant of the project, accurate email address must be provided, and user can check his/herself as a begginer, some ID training, or an expert according to his/her knowledge

level. This project only track the statistic data like how frequently users log in for research use. No personal background data has been collected.

- User number

Abandoned Developments

Based on the information provided by Google Analytics, the number of site visits, absolute unique visitors, and visitor locations have been captured (Werts et al. 2012). The analytic data is available from March 27, 2011 to October 30, 2011, recorded by the project runners. The site received 154 visits on the first day of release (March 29) and 123 visits the following days; averagely it received 8 visits per day. Visitor locations concentrate in South Carolina. The number of total visits of the Web-mapping interface is 413, and 46% of them attempted to use the Silverlight WebGIS to upload data.

CoCoRaHS

CoCoRaHS was set up and launched by three high school students under the local funding. Beginning from several dozens of enthusiastic volunteers in 1998, the number of participants is increasing in each year. Table 3-5 shows the number of active volunteers and involved counties from 1998 to 2004. Besides active volunteers, there are some people participated in this program for a few weeks but not remained active in a long term. In the year of 2000 *CoCoRaHS* received a fund from the NSF Geoscience Education program, then it hired a Webmaster and a volunteer coordinator. In the year of 2008, this program had 7,500 volunteers in more than 26 states. From 1998 to 2008, more than 13,000 individuals and families have signed up to help. Now this project has been

developed in all 50 states. Based on the real-time statistic data, around 8,000 daily precipitation reprots received everyday in 2013.

Year	Active volunteers	No. of Colorado counties
1998	110	1
1999	240	3
2000	358	6
2001	432	9
2002	582	22
2003	760	43
2004	1036	60

Table 3-5 Number of Volunteer and Involved Colorado Counties

eBird

Since *eBird* released in 2002, over 500,000 users have visited this site. The project has gathered over 21 million bird records submitted on more than 1.6 million checklists. Over 35,000 unique users have entered data into *eBird*, from more than 180,000 locations across the Western Hemisphere and New Zealand. Chart 3-2 showed the numbers of observations through 2003 to 2008.

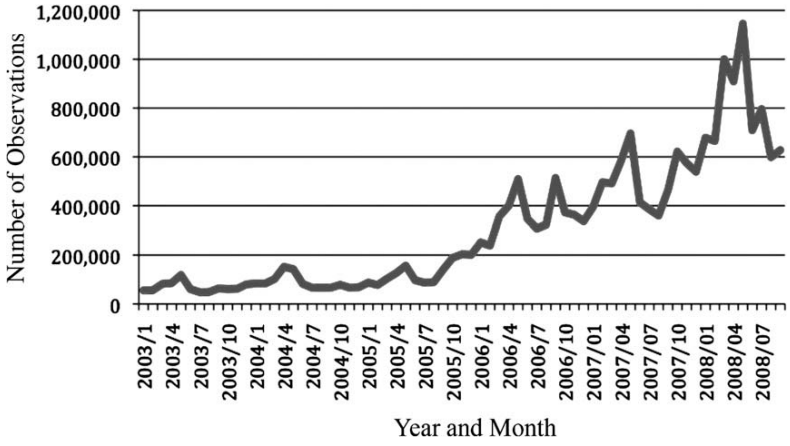

Chart 3-2 Number of Observations 2003-2008

OakMapper

Since its launch in December 2008, *OakMapper 2.0* consistently receives about 200 visitors per month. And the number of registers is 49 and includes 4 government officials. *OakMapper* began downloading Twitter feeds tagged with "Sudden Oak Death" in April 2010 and has acquired 287 Twitter feeds including 12 geo-tagged points; it has downloaded 107 geo-tagged Flicker photos; iPhone app has been downloaded 94 times since it released in October 2009 but few points have been submitted by using the application.

OpenStreetMap

Since its foundation in 2004, up to 2008, *OpenStreetMap* had more than 33,000 registered users, including approximately 3,500 currently active contributors, and about 40 volunteers to help creating and improving infrastructure. Comparing with Wikipedia's individual contributor, *OpenStreetMap* community organizes a series of local workshops (called "mapping parties") to create and annotate content for localized geographic areas. Up to November 2012, *OpenStreetMap* had over 900,000 contributors. However, a small number in the whole users contributed the majority of the content. According to the statistic data, in 2008, approximately 10% of the registered users contributing the *OpenStreetMap* each month, and in the year of 2011, this number decreased in around 3% (OpenStreetMap Wiki, 2013).

What's Invasive!

According to the latest (May 2013) data updated on the official website whatsinvasive.com, there are currently 290 registered users who have contributed 10936 observations of 191 invasive species in 110 active parks.

3.4.3 Information

- Objective

Abandoned Developments

Based on the full project description on its official Website, a large number of unfinished residential construction sites exists in upstate South Carolina due to the burst of the housing bubble in the past several years. These unfinished construction sites may cause soil erosion and pollute the water bodies like streams and lakes nearby. The founders of this project have done some researches about this problem: they studied in Greenville, Spartanburg, and Pickens counties, and found out there are more than one hundred unfinished residential constrution sites in these three counties. A large number of these sites lie in sparsely populated area and hardly to be found in a short time. Sediment release to water bodies has been occurred in many of these sites and this situation may harm local aquatic ecosystems. The project team members are limited and they cannot reach every site in this study area, so this project needs public to help collecting as much information as possible. Greater public involvement in this study is not only a new way to collect data, but also a possibility to limit future sediment pollution by increasing public awareness and changing laws and policy (Werts et al. 2012). A sample of previous study has been posted on the interactive map, users can click the "Original Study" button to see

it. This example shows the location, picture, and description of the sites. Users can take these information as a reference to evaluate the possible sites. Besides the sample demonstration and users submission, this WebGIS interface also allows users to view and comment each other's submissions.

CoCoRaHS

CoCoRaHS's objective is providing the accurate high-quailty data of precipitation for natural resource, education and research applications on a timely basis. It is a community-based project, encouraging public to get involved in it is also a goal. By offering interesting training and education programs, *CoCoRaHS* tries to increase public awareness about climate and to develop their skill in data collection. Besides collecting data from observers, this project also collaborating with other existing precipitation neteworks to provide comprehensive precipitation information. The interactive Website is used for data submitting and presenting. Observers can input their recording data online to the project; and all users can check each day's national or state precipitation/snow/hail data from the interactive map.

eBird

eBird is a citizen science project, which provides standard protocols to observers for reporting birds observations. The goal of this project is taking advantage of citzen scientists' power to collect birds data as much as possible in a large spatial and temporal scales. Data submitting process is through a simple and intuitive Web interactive queries. eBird treats the Internet tool as an encouragement for long-term contributers since it is easy to access and visualize data. *eBird* also offers a checklist about the bird species and

abundance as a reference to users. *eBird*'s Web-interface is available in English, Spanish, and French.

OakMapper

Sudden Oak Death (SOD) is occuring along the coast of California and sourthern Oregon, threatening the ecology. Inspired by the USGS Earthquake Mapper, researchers thought citizen scientists may help collecting SOD data. Integrate with the official data, community-submitted data can help researchers to get a broader understand of SOD. As monitering this disease need the coorperation of both governmental agencies and general public, an interactive Website – *OakMapper* has been established to coordinate and demonstrate SOD data. *OakMapper* tries to provide users an easy and simple operating experience, first-time user can submit geographic information about SOD through *OakMapper* without any technical obstacles that tranditional GIS brought. For instance, users can use the zoom and pan tools to report a SOD location without knowing the exactly xy coordinates. Also users can submit data through other services like iPhone application, Flicker, and Twitter. On the interactive google map, users can check any existing data by clicking the point to see the detailed information.

OpenStreetMap

OpenStreetMap aims to create and demonstrate free geographic information to all users around the world because other maps are not totally free to use since they have legal or technical restrictions. It considers the built environmental issues. After creating an account, users can upload the geographic data they collected by GPS, local knowledge, or

aerial imagery to the interactive interface, then they can edit the data and maps. *OpenStreetMap* supports more than 40 languages.

What's Invasive!

What's Invasive!'s objective is to alert public the spread of habitat-destroying invasive species and provide scientific data for research and environmental management by take advange of citizen science – encourage general public observe, locate, and make public the invasive species. The project use the smart phone as a tool because it has the GPS function that can upload geo-tagged picture to the database. To join in this project, users need download the *What's Invasive!* application to their smart phone, create an account, and upload data. Users can also submit data online to the EDDMapS (Early Detection & Distribution Mapping System), a national invasive species database.

- Data

Information collected by these websites can be general information or specific information.

Abandoned Developments

The *Abandoned Developments* project intends to collect specific data about the location and picture of the unfinished residential construction sites. Based on the data (Werts et al. 2012), at least 290 Original Study Data photos were viewed and at least 105 User Submittals photos were viewed, ten submissions were completed during the analysis period (March 27 to October 30, 2011).

CoCoRaHS

CoCoRaHS collects the timely, useful and spatially detailed local specific data about the precipitation, include rain, hail, and snow. Then this project can provide the detailed and timely data and maps (Figure 3-3 & Figure 3-4) to all kinds of users: governmental agencies like USDA, the National Weather Service and city utilities (water supply, water

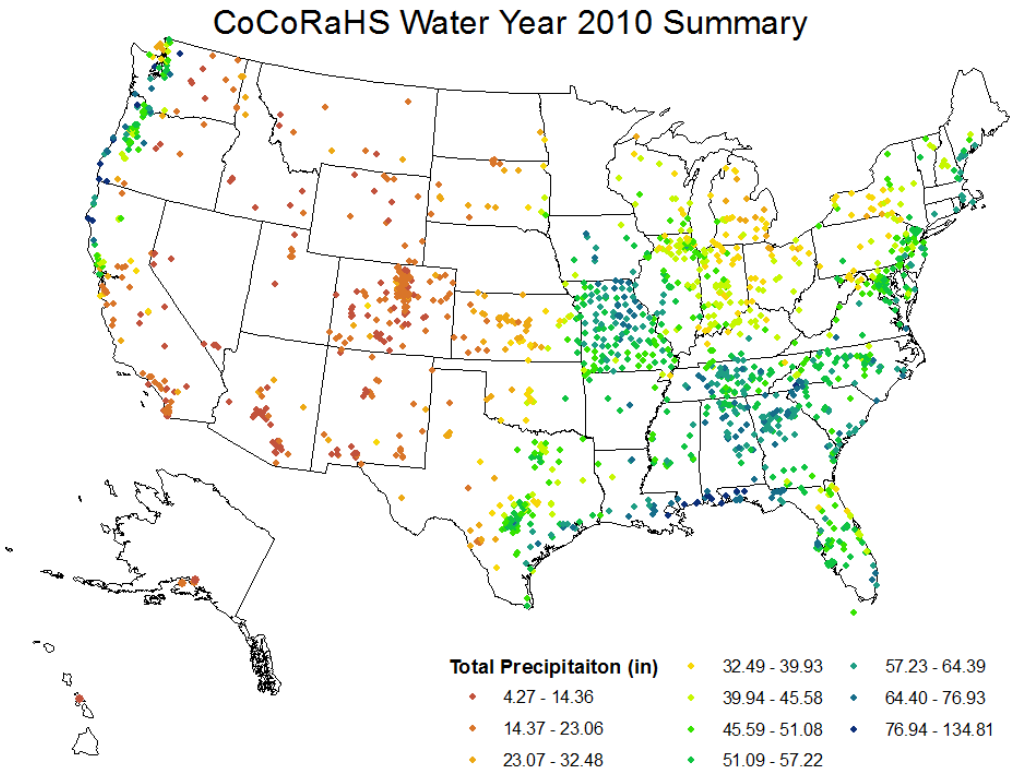

Figure 3-3 *CoCoRaHS* Water Year 2010 Summary, U.S.

conservation, storm water), researchers or professionals like meteorologists, hydrologists, emergency managers, insurance adjusters, engineers and mosquito control, and general public users like ranchers and farmers, outdoor & recreation interests, teachers, students, and neighbors in the community.

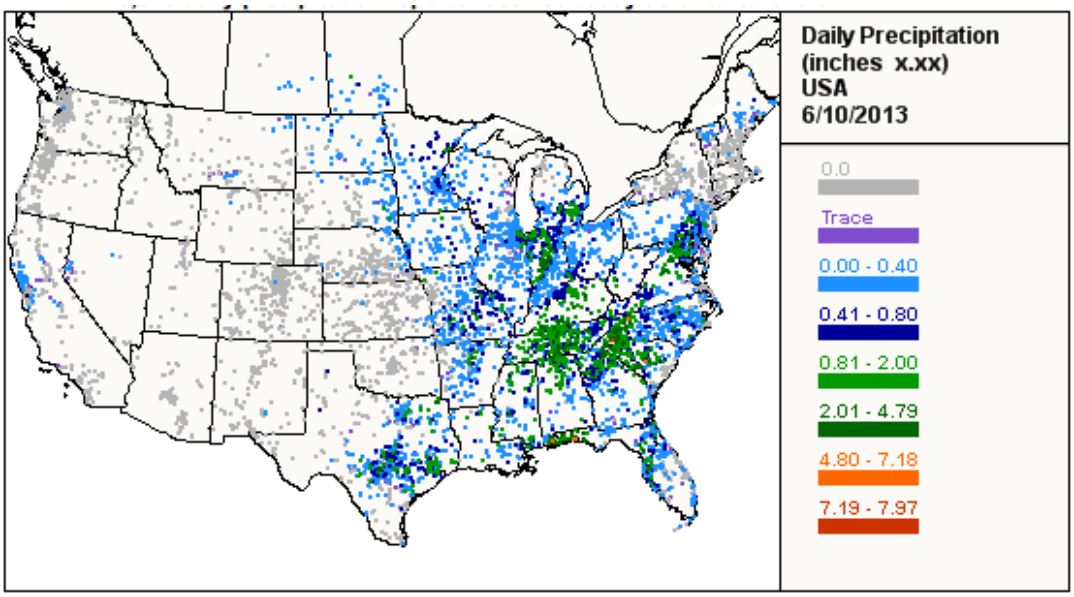

Figure 3-4 Daily Precipitation Data Summary, U.S.

eBird

eBird collects the specific data about personal bird observations. Useful data are about recording all species, travelling counts, stationary counts, area count, random count, incidental observation, and a note on estimations. What's more, eBird provides a data verification process to ensure the quality of the data. A combination of automated filters and a network of regional editors have been developed by using advanced data vetting technology – they are working together to verify *eBird* data.

OakMapper

OakMapper collects the specific data about the SOD. Including geo-tagged information about the location and area of trees with disease, geo-tagged photos showing both location and image information. According to the statistic (Connors, Lei, and Kelly 2012), including data collected from the previous version of *OakMapper*, the database contains a total of 663 unconfirmed community-submitted points and 1,134 officially confirmed points. Also, as mentioned before, it collected 287 Twitter feeds including 12 geo-tagged points and 107 geo-tagged Flickr photos.

OpenStreetMap

The data collected by *OpenStreetMap* are all about streets: name, shape, and direction. Besides data collected by individuals, some governmental agencies have released official data with appropriate licenses, and some companies provided actual street data and satellite imagery sources. *OpenStreetMap* uses a topological data structure, with four core data primitives: nodes (position with latitude and longtitude), ways (polyline or polygon), tags (store metadata about the map objects), and relations (representing the relationship of existing nodes and ways). Based on the statistic data from *OpenStreetMap* wiki, up to May 27 2013, the statistic data shows the number of users is 1,218,063; number of uploaded GPS points is 3,422,456,735; number of nodes is 1,910,058,472; number of ways is 184,774,228; and number of relations is 1,972,770.

What's Invasive!

What's Invasive! collects the general data about the invasive taxa and species. As mentioned before, users have submitted 10,936 observations in 110 active parks. In its

official website, data can be viewed by each park. Take Rocky Mountain National Park as an example. With the contribution from public, 75 invasive weeds have been found in this park. The Website provides top invasive plants' name and picture, and each picture has the credit to see who is the photographer/contributor.

3.4.4 Site use

Based on MacEachren's (1994) theory, the interaction between human and map can be high if users can manipulate the maps in substantive ways; and low, if users have limited ability to change the map presentation. According to Connors, Lei, and Kelly (2012), the degree of user's intention to contribute to a database for a specific purpose can define the interaction. That means, the intentionality can be very high if the data provided by users were directed at a specific database in a particular project, or low if they were directed elsewhere. Our six case studies, *Abandoned Developments, CoCoRaHS, eBird, OakMapper, OpenStreetMap*, and *What's Invasive!*, are all requiring high intentionality and interaction with the database from the users.

- Communication platform

Abandoned Developments

Abandoned Developments' communication platform is on the Silverlight viewer. Through this interactive map, participators can comment other's submissions. No guarantee that all the comments will get the responds from the uploader, project runner, or expert. This project leaves the program email address, mail address, office phone number, and toll-free phone number for participators who have questions or concerns about this project.

Abandoned Development has a Facebook page for connecting current or prospective users.

CoCoRaHS

CoCoRaHS has plenty of off-line activities for weather observers gathering and communicating, including training sessions, field trips, special speakers, picnics, pot-luck dinners, photography contests, etc. These activities provide a platform to let the participators meet and know each other, and solve some problems under the guidance of others or specialists. There are local *CoCoRaHS* volunteer coordinators in all fifty states, and they will answer participators' questions. Also, *CoCoRaHS* has some Web groups like *CoCoRaHS* blog to share the weather information and unofficial *CoCoRaHS* groups for discussion. *CoCoRaHS* discussion group sites include *CoCoRaHS* Facebook group; Yahoo groups of Jackson County Indiana *CoCoRaHS*, State of New Jersy *CoCoRaHS*, Washington State *CoCoRaHS*, Missouri State *CoCoRaHS*, Alabama *CoCoRaHS*, Florida *CoCoRaHS*, and Mid-Atlantic states (MD, VA, DC, PA) *CoCoRaHS*; and Google discussion group of Vermont *CoCoRaHS*.

eBird

eBird has a Google discussion group named *eBird* TechTalk to allow users communicate with each other. If users have questions, they can go to the online help center and post their questions, the feedback will reach to them via email. Also, users can send email to the project directly. The Facebook page of *eBird* is used for communication with users too. eBird project has off-line activities like education or training programs.

OakMapper

On the interface of *OakMapper*, logged-in users can make comments under either offcially confirmed or community submitted point or just report whether have seen it or not to confirm the report.

OpenStreetMap

OpenStreetMap has a community blog Website (blogs.openstreetmap.org) for users to post their ideas and communicate with each other. This blog site connects User's Diaries site. It is very active, everyday there are several users post ther blogs/diaries online. Users can post their questions on the help page of *OpenStreetMap*, and most questions will be answered. According to the statistic data, up tp May 28, 2013, there are 4,620 questions and 7,193 answers. Also, *OpenStreetMap* has off-line activities, mostly is the "mapping party" for users to meet each other and discuss in person, or do the mapping together.

What's Invasive!

What's Invasive! does not provide communication platform for smartphone application users, neither for Web-page users. If users have questions, they can contact the project runners directly via the email. This project does not have a Facebook page.

IV. RESULTS

This chapter will further analyze the current conditions of each case under the criteria. Firstly, the number of user and data submission will be analyzed to see if there is a relationship between these two. Secondly, this study will use the number of data submission per person as the indicator of project interaction; and the relationship between project task and interaction will be analyzed. The third part is the SWOT analysis. SWOT analysis is used as a structured planning method to evaluate internal strengths and weaknesses, and external opportunities and threats of a project, to provides a basic outline for decision making (USDA 2008; Shojaei, Abbaszade, and Aghaei 2013). Through the analysis results, the current condition of using Internet-based PPGIS in environmental management field will be generally understood, lay a foundation of making suggestions for future better use.

4.1 User and Data Submission

Table 4-1 shows the active user number, data submission number, and the calculated data submission number per user in a certain time period of each project. Active users are those who registered and attempted to submit data. In the year of 2011, from March to October, 190 visitors tried to use Silverlight WebGIS upload data to *Abandoned Developments*. And during this period, 10 submissions have been completed. In average, one user contributed 0.05 submission. If one submission is completed by one user, that means 5% active users have successfully submiited data to this project. From 1998 to 2008, more than 13,000 individuals or families signed up as volunteers in *CoCoRaHS*. According to the latest statistic data in 2013, *CoCoRaHS* received about 8,000

precipitation reports everyday. The number of submission per user is 0.61. From 2003 to 2008, there are 35,000 registered *eBird* observers, and the number of total observation submissions is 21,000,000. In average, each user uploaded 600 observations to *eBird*. From December 2008 to 2012, the number of community-submitted points of *OakMapper* is 663. This number not includes officially confirmed points and the data submitted via social media. The number of registed users is 49 in this period and the average number of submissions per user is 13.53. From 2004 to 2013, the number of active users of *OpenStreetMap* is 1,218,063. *OpenStreetMap* collects the street data that include nodes, ways, tag, and relations. The number of ways is used as the number of submissions in this study, and the number of average submissions per user is 151.69. From 2002 to 2013, the number of average submissions per user of *What's Invasive!* is 37.71.

	Active users	**Submissions**	**Submissions per user**	**Time range**	**Comment**
Abandoned Developments	190	10	0.05	Mar. 2011 – Oct. 2011	
CoCoRaHS	13,000	8000	0.61	User: 1998 – 2008; Data: 2013	Daily submission
eBird	35,000	21,000,000	600	2003 – 2008	
OakMapper	49	663	13.53	Dec. 2008 – 2012	Community-submitted points, not include data submitted by social media.
OpenStreetMap	1,218,063	184,774,228	151.69	2004 – May 2013	Use the number of ways as the submissions
What's Invasive!	290	10936	37.71	2006 – May 2013	

Table 4-1 User and Data Submission

Project	Time range (Year)	Number of users
Abandoned Developments	0.67	190
OakMapper	4	49
eBird	5	35000
What's Invasive!	7	290
OpenStreetMap	9	1218063
CoCoRaHS	10	13000

Table 4-2 Time Range and User Number

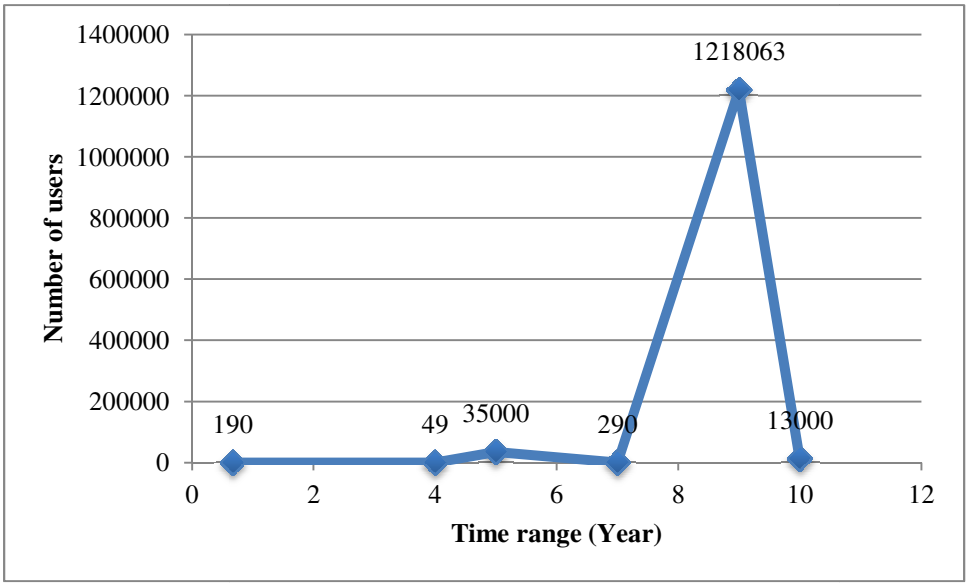

Chart 4-1 Time Range and User Number

Table 4-2 and Chart 4-1 show the relationship between time range and the number of active users. According to the data, there is no linear relationship between them. That means increase of the duration of a project cannot guarantee the increase of the number of participators. A project like eBird attracted more users in five years than *CoCoRaHS* in 10 years. The number of users may related to other factors like the project coverage area. For instance, the project involves the largest amount of participators in this study is *OpenStreetMap* – a worldwide project. What is more, the issue a project addressed and the operation condition of a project are the factors will influence the number of

participators. To some extent, more users will bring more submissions; however, more users do not mean the high interaction between all registered users and the site. According to *OpenStreetMap's* statistic data, in 2008, only 10% registered users contributed to this project; and in the year of 2011, this number decreased in 3%. It is undeniable that in some projects most contributions are completed by a small group of people. In this study, the average number of submissions per person is used as the indicator of interaction.

4.2 Task and Interaction

Project	Task	Submissions per user
Abandoned Developments	Abandoned residential construction sites	0.05
CoCoRaHS	Precipitation	0.61
OakMapper	Trees suffering SOD	13.53
What's Invasive!	Invasive species	37.71
OpenStreetMap	Streets	151.69
eBird	Birds observation	600

Table 4-3 Task and Interaction

This thesis mentioned that small but certain task would help attracting long-term and active contributors previously. As showed in table 4-3, among these six cases, the one has highest interaction is the eBird program. *eBird* has a certain but not small task. *eBird* has a checklist for data reporting. During 2003 to 2008, the over 21 million bird records submissions are based on more than 1.6 million checklists. For instance, *eBird* provides a more than 170 birds in about 40 categories checklists at the hotspot Antelope Park 33rd walk, Lancaster County, Nebraska. Citizen scientists contributes to the large database and the database also supports data collection back. *eBird* and the project has second highest

interaction – *OpenStreetMap* have a common point: a group of certain and long-term active contributors. *eBird* attracts birds observers, a group has good and fixed habits of birds observations. Watch *birds* not a new action but a routine in their daily life, and the new thing is to report their observations to a global data base, which will arise their sense of achievement. Similarly, users contributed most to *OpenStreetMap* are those who interested in mapping and they often forming into groups to work. In contrast, the programs like *Abandoned Developments* and *OakMapper* have no massive user base. Few people will intentionally notice the abandoned residential construction sites or the trees suffered SOD in their everyday activities. Besides specialists who study or work on these fields, general public who want to participate in these programs should keep their eyes on the unfamiliar things on purpose. Unfamiliar task is an obstacle to public engagement. Another remarkable thing is the interaction level of *CoCoRaHS*. The number of submissions per user in *CoCoRaHS* is only 0.61, however, this number does not mean the low interaction of this program. Since this project collects daily data and each observer submit one copy of data, this number means more than 60% registered users are actively contribute to the database everyday. *CoCoRaHS* program is about weather, which is closely related to citizen's daily life. According to previous analysis, the task of a program will influence the interaction between users and the site. If a task is familiar to most or a certain group of people and closely to their everyday life, the project will have higher participation level. If a project addresses a special task, target user group should be defined rather than try to involve general public. When the target user group has been defined and organized, education or training programs and off-line activities could be offered to stimulate users' enthusiasm.

4.3 Platform and Interaction

There are two major kinds of the interactivce platform in this study. One is submit data through a checklist, like *CoCoRaHS*, *eBird*, and *What's Invasive!*; the other one is directly submit data on the interactive map, like *Abandoned Developments*, *OakMapper*, and *OpenStreetMap*. In this study, the first platform is called indirect mapping platform and second one is called direct mapping platform. For the indirect mapping platform, users can view their data on map and on statistic table or chart after the project runners processing and integrating the raw data. Table 3-4 shows the platform of each project and their interaction level.

Project	Platform	Submissions per user
CoCoRaHS	Indirect mapping platform	0.61
What's Invasive!		37.71
eBird		600
Abandoned Developments	Direct mapping platform	0.05
OakMapper		13.53
OpenStreetMap		151.69

Table 4-4 Platform and Interaction

According to table 3-4, the type of platform seems has little influence on the interaction level. This study considers the type of platform as a possible influencing factor to the interaction is because a type of platform may have the absolute advantage in user-friendly operation, which will stimulate public participation. However, both indirect and direct mapping platform have pros and cons, and these two types have no significant difference in operating convenience. For instance, *eBird* users upload their birds observations through a checklist. First, users should confirm the location by using an existing hotspot, creating their own locations, finding on the map, or using latitude and longtitude. After

confirming the time and observation type, observer can just choose the bird species they heard or saw from the checklist, they also can add a new one if the checklist missed it. After integrating and verifying data, users can explore the data online through the interactive range and point maps, bar charts, line graphs, and real-time submission map. In *OpenStreetMap*, general public with little GIS experience can use Potlatch, a lightweight online Flash-based editor, to edit the map. Users can simply add, update, or delete geographical features on the interactive map, and their outcome will reflect in time. Choosing a indirect or direct mapping platform for a project is based on what kinds of data it wants to collect. Comparing with projects with direct mapping platform, the projects with indirect mapping platform collect more complicated data besides the time and location. *CoCoRaHS* observers report the 24-hour precipitation (total rain, snow, or ice melted) and the snow measurement everyday. When extreme weather occurs, observers need report other specific information about hail, droughts, flood, etc. For example, hail information including hail size, hardness, color, rain, damage, hail pad information, etc. Users of What's Invasive! should choose a park first to report, and then select the invasive species they saw from the list. Moreover, the amount of this invavise species will be asked and a geo-tagged photo is preferred for data verification. Relatively, projects with direct mapping platform collects single type of data. *Abandoned Developments* located the site of abandoned residential construction sites and *OakMapper* located the trees suffered from SOD, users just need to verify the location on the map and report what they found. Actually, there is no strict boundary between these two platforms, indirect mapping platform also use map to confirm location.

Another remarkable platform in these project is the communication platform. Table 4-5 shows the relationship between the communication platform and the interaction level of each project.

Project	Communication platform		Submissions per user
	On-line	Off-line	
Abandoned Developments	Interactive map, social media.		0.05
CoCoRaHS	Blog, discussion groups, social media.	Training sessions, field trips, special speakers, picnics, pot-luck dinners, photo contests, etc.	0.61
OakMapper	Interactive map.		13.53
What's Invasive!	Email for questions.		37.71
OpenStreetMap	Blog, user's diaries, help page, social media.	Mapping party.	151.69
eBird	Discussion group, help center, social media.	Training and education programs.	600

Table 4-5 Communication Platform and Interaction

Projects have wider coverage, longer history, and greater influence paying more attention on the user communication. *CoCoRaHS* has local coordinators in all fifty states, and the coordinators are responsible for most off-line activities. *OpenStreetMap* and eBird have spontaneous off-line activites among participators. With the help of Conrnell Lab of Ornithology, "Sal a Pajarear" (which means "Go Out Birding") project led by nonprofit Club El Tamarindo in the Mexican state of Jalisco tought more than 100 students about the knowledge of ecosystem by watching birds, and the group becomes the state's leading eBird checklist contributors. *OpenStreetMap's* mapping party is not only for mapping skill training (teach beginners how to use GPS devices and JOSM to edit map) but also for social gathering. According to the event calender, each month there are quite a few

mapping parties all around the world. Off-line activity is helpful to attract and retain long-term active users, but it has limitation – some small projects cannot afford the costs for coordinator, devices, time, and place. Fortunately, on-line communication platform is affordable to every project. However, although some projects provide the on-line communication platform for users, it does not facilitate real two-way communication since the feedback is not timely. For example, *Abandoned Developments*, after users make comments on the submissions, there is no guarantee they will get the feedback, and this may kill the users' motivation of contribution. Most of the selected projects use the social media like building up their own Facebook page to facilitate public awareness and engagement, but effective and successful social media communication also needs careful management, like update recent developments and communicate with participators in time.

4.4 SWOT Analysis

4.4.1 Strength

Internet-based PPGIS is a new platform for involving general public in environmental problem solving. Comparing with traditional techniques for facilitating public engagement, it broke the limitation of time and space, and with proper technical support, the limitation on participants could be broke too. Ideally, it is a platform allows every interested person to use in any place (with Internet accessed PC or other devices) any time. Comparing with traditional GIS software, the advantage of this new platform is the simplicity. All participatory Websites in this study are user-centered design: they are easy to operate even for beginners. On the interactive map, users can apply the pan, zoom,

search, edit, or delete function by simply click one button. Projects using checklist to upload more complicated data like *eBird* also have simple and user-friendly operation interface.

With the development of technology and the popularity of Internet and computer (according to Internet World Stats, over a third of the world's population have used the services of Internet; and according to the report of KPCB – Kleiner Perkins Caufield Byers in 2010, there are more than 1.4 billion in the world), this new platform will help attracting increasing number of people take part in the environmental management. All participatory Websites in this study are welcome all users without background check (some projects have the age restrictions – older than 13 years due to COPPA) even they have a target user group. All citizen science projects in this study try to attract users as much as possible, Internet-based PPGIS offered an opportunity for them. Although the number of user varies in project to project, every project is functioning well and attracting public intention successfully.

After attracting a certain amount of people, an important function of these project Websites is informing the professional outcome completed by each research project team earlier or the officially confirmed community-submitted data to the public and increase their awareness of this environmental issues. Original study of Abandoned Developments illustrates what an abandoned residential construction site looks like and its potential damage to the water body nearby. The location of trees suffered SOD reminds people realize the scale of the issue and its seriousness. Usually, people can only access these data through the professional research papers or reports, which are unattractive and un-friendly to general public. Internet-based PPGIS makes science more approachable.

When people found this is an interesting/important issue and realized they can also contribute to the problem-solving or decision-making process, Internet-based PPGIS provides a platform for the real participation – data submission. During the analysis period of each project, some projects collected very large amount of public-submitted data like *eBird* (21 million birds observations in 5 years), *OpenStreetMap* (184 million ways in 9 years), and *CoCoRaHS* (about 8 thousand precipitation data in everyday); and for the relatively small projects like *Abandoned Developments* also has a good result – 10 submissions in 7 months. Besides in educating public, all these citizen-submitted data have a significant use in scientific research: like *eBird* data are used by educators, land managers, ornithologists, and conservation biologists.

As stated before, public participation plays an important role in environmental management: it can relieve contradictions, stimulate the forming of shared vision and creative solution for the environmental issue that covered a huge range of values. Internet-based PPGIS, a user-friendly participatory GIS tools is helpful in solving large-scale and long-term environmental management problems. On the one hand, the function of demonstration and communication is like an educator for general public; on the other hand, the function of data submission allows everyone becoming a citizen scientist to contribute to the scientific research data collection.

4.4.2 Weakness

One goal of treating environmental management as a citizen science project is to involve more people to get more data. To some extent, theoretically a larger user base can bring more data submission proportionally. However, in some programs, most data are

submitted by a small portion of active users. Like as the 2011 statistic data of *OpenStreetMap* showed, only 3% registered users contributed to the database. Because other cases did not mention the actual number of users who successfully update data (the submission number cannot be seen as the actual user number since a user can submit more than one copy of data in most cases), the average number of submissions per person is used as the test criterion for public participation level. Although the degree of public participation is not low in most cases in this study, a noticeable point is that even the high degree of participation brings large amount of citizen-submitted data, it is not equal to bring the large amount of useful data. This is the problem of data quality.

Data quality issue has been largely discussed in the fields of VGI and citizen science, and all other fields use general public collect data for scientific research. Use citizens collect data breaks the limitation of information: previous researches have to rely on the single source to get the data, result in staying in a passive position and lack of innovation. However, behind the ubiquitous data is the problem cannot be ignored – data quality. There are two major factors affecting the data quality – user's judgment and operation. User's judgment is based on his/her own understanding and knowledge. Although projects provide examples or checklists for users, the judgment is still made by themselves. For example, to decide one oak tree is suffered the SOD or other disease, or to affirm the species of the observed bird, all the judgments based on observers' knowledge and experiences. However, even specialists will make mistake, the misjudgment is inevitable in reality. Another inevitable mistake is misoperation. Unfamiliar with the operating interface, distraction, and even no reason can cause incorrect operation. If the theory that more users will bring more data submissions is

accepted, possibly more data submissions will bring more mistakes that will reduce the data quality. What is more, find the wrong data in a large database is not a very easy task.

Some projects provide the data verification process to guarantee good data quality. A positive example is *eBird*. *eBird* built automated data quality filters based on the regional bird experts' knowledge and experience. If an unusual observation, like a bird species never found in this place before or the amount of birds is unreasonable, the filter will mark this observation as an unusual record, report to local experts for examination and verification. Automated filter may miss the rare but real observations; use local experts to double check the data can reduce the probability of this error, with new problems – time and money consuming. Hire local experts to evaluate data is not a small expenditure for a program; and the time-consuming problem will reduce one advantage of Internet-based PPGIS – data timeliness. In general, there is no perfect solution for the data quality issue for now. Actually, "perfect" solution would never exist, and how to improve data quality in citizen science project is a burning question for relative professionals and scholars in the future for a long period of time.

4.4.3 Opportunity

Taking advantage of Internet-based PPGIS to facilitate public participation in environmental management is a new technique. The merits of this new technology are stated before, but it is not a substitute of the old ways to facilitate public participation – cooperate well with them will maximize its effectiveness. Previous analysis result shows that long-term successful programs like *CoCoRaHS*, *eBird*, and *OpenStreetMap* use the off-line activities to attract new participators and retain old users. Some activities like

inviting special speakers or creating study group are useful before the advent of this new technology. Although these activities have limitation on numbers of gathered citizens while comparing with Web-based technique, they can be used in small scale like community area with the help of volunteered local coordinator. Face-to-face communication cannot be replaced by the Internet-based or other kinds of communication techniques because it is effective, it can build the sense of personal connection, and allow nonverbal communication and personal touch. Both on-line and off-line communication can strengthen the bonds between participators, and then raise users' interest of participation.

Social media, built on Web 2.0, is an Internet-based virtual community for people to create, share, and exchange information (Ahlqvist et al. 2008, Kaplan and Haenlein 2010). Social media can largely promote the on-line communication since it becomes increasingly popular in recent years. According to the statistic data (Nielsen 2012), in July 2012, people spent 121 billion minutes in total on social media in the U.S; Facebook, as the most-visited social network in the U.S., has 901 million users as of May 2012, and the number of Facebook visitors is 152 million via PC, 78 million via mobile apps, and 74 million via mobile web. One objective of using Internet-based PPGIS in environmental management is similar to the function of social media – create, share, and exchange data. Actually, social media is treated as an inextricable part of the Internet-based PPGIS in the first place. Most programs set up their Facebook page and some built on-line discussion group for communication. *OakMapper* users can submit data – geo-tagged photos via social media like Twitter and Flicker. All of these are good starts,

although the Internet-based PPGIS and social media are not closely linked yet. The future of this integration is promising and need more attention.

No matter on-line or off-line activities needs careful management, which ask for human, physical and financial resources. This is a heavy burden for small programs. To solve this problem, program can cooperate other organizations – from non-governmental to governmental, from local to global. Like *eBird* guides a non-governmental organization in Mexico, cooperates with local primary schools, provides education program to students and the group becomes the top contributor to *eBird* checklist in local. *CoCoRaHS*, cooperates with educators and middle schools to teach students the knowledge about weather and climate – middle school students are active contributors to this project. In these cases, school is the best and most common partner, but the cooperation should not be confined to it as education is not only for students. According to the issue to be solved, each project can choose different cooperate partners. For instance, Abandoned Developments can work with community-based organizations to organize and train residents to find the abandoned residential construction sites in their own communities; and *eBird* can cooperate with local birding groups or organizations if they are already existed. Cooperation will make the shared purposes much easier to achieve.

4.4.4 Threat

Common motivation of participation is based on participation itself – it is good, it works, and in most time it is required. But this motivation seems too vague for individual participators; specific motivation of each project should be clearly stated. Specific

motivations include but not limited to build a shared vision, foster the sense of responsibility and commitment, and provide fun and hands-on involvement process. Moreover, incentives can be used to attract and retain long-term and active contributors. Besides monetary incentives, incentives like award, give people ownership, provide timely feedback are used to increase people's sense of achievement. Education program can be treated as an incentive because it can give people an opportunity to learn interesting and useful new knowledge and to meet new friends. Motivation of participation is very importance to citizen science project and it varies from project to project. If a project did not find the appropriate motivations or the current motivations just do not work, the foundation of this project will be shaky, and this is a great danger.

A vital advantage of Internet-based PPGIS in environmental management is strengthening the links among different environmental manager groups by providing them an instant communication platform. However, in some cases, this connection is not as strong as expected. On the interactive map interfaces of *Abandoned Developments* and *OakMapper*, users can make comments on other's suggestion; but these are not real two-way communication platforms because the accuracy and timeliness of the feedback are not guaranteed. That means even if an ideal condition is prepared, there is a possibility the goal cannot be achieved. Lack of active and timely two-way communication may make this new technique become a "shiny box", inferior to the effect of traditional face-to-face ways.

Although Internet service and user terminal like PC and mobile devices are very popular in contemporary society, it is undeniable that some groups of environmental managers cannot access to this new platform. For instance, besides the basic participation

requirement – a device with Internet access, measure precipitation needs tools; GPS devices are preferable in uploading map data to *OpenStreetMap*; *What's Invasive!* application and geo-tagged photos require smart phones. What is more, according to *OakMapper's* study, university-educated individuals could contribute more accurate data. Some projects are inclined to use students as primary contributors. This tendency also causes the unequal participation.

There are some prerequisites in using Internet-based PPGIS in environmental management. First, it suits for solving highly visible environmental problems in order to involve large amount of general public. Second, the best type of collected data is quantitative data for better illustration in GIS. Therefore, this technology cannot be used in every environmental management issue; it is not a master key should be carefully noticed. Generally, Internet-based PPGIS cannot solve the environmental management problem once for all. It does have advantages in facilitating public engagement, but these advantages still need investment and management to keep.

Figure 4-1 is a summary of the summary of the SWOT analysis results.

Figure 4-1 SWOT Results

V. DISCUSSION

5.1 Practicability of Internet-based PPGIS in Environmental Management

In this section, the possibility to use Internet-based PPGIS in environmental management will be discussed. According to previous a analysis, advantages and disadvantages of Internet-based PPGIS used in the selected cases have been preliminarily understood. It is clearly that Internet-based PPGIS provides a simple and easy-to-use platform to attract more public users; this platform can increase the public awareness of environmental issues as well as collect community-submitted data. However, this new technology, a tool for facilitating public participation in environmental management process, also has weakness – data quality issue. At the same time, using this tool is under the threat of lacking motivation, failed two-way communication, uneqaul access, limited data types, and the ignorance of lasting investment and management. Fortunately, there are still several opportunities – cooperate with traditional communication techniques, social media, and other organizations. This thesis will provide suggestions for better use of this tool in environmental management field, based on the notions of keeping the strengths, improving the weaknesses, responding to the threats, and seizing the opportunities. Each suggestion will be generally demonstrated and a specific case – take advantage of Internet-based PPGIS to promote environmental justice will be used to concretely explain these suggestions.

5.2 Background of Environmental Justice

Environmental justice is a relatively new term. It is an aspect from the social justice, and can be traced to the term justice – a controversial philosophic topic has been debated since Plato's age. In contemporary society, several organizations or scholars who paid attention to this area give the definition of environmental justice about pursuit of fairness, regardless of all backgrounds, and environmental laws, regulations, and policies (Arnold 2007; Bryant 1995; Millner 2011; U.S. EPA http://www.epa.gov/environmentaljustice/). What is more, in Millner's (2011) research, environmental justice has five aspects – recognition, participation, precaution, fair distribution, and compensation. According to these descriptions, environmental justice has two important essentials. On the one hand, it requires the fairness of distribution of both nautral resources and hazardous facilities and equal protection from pollution. On the other hand, it can give everyone the equivalent opportunity to know and to participate in the decision-making process related to environmental issues. In general, today, the definition of environmental justice becomes increasingly comprehensive. It is not only focus on the passive distribution and protection, but also address the active motion – participation. The unfair distribution of hazardous facilities (socio-economic status decreases with the density of hazardous facilities increase) can be seen locally, nationally, and internationally (Anderton et al. 1994; Hird 1993; Greenberg 1993; Walker and Bulkeley 2006; Walker 2009). Unfortunately, the more important and urgent problem is for most disadvantaged groups, they did not know they bear a disproportionate burden of environmental hazards, let alone object to such decisions or try to improve this situation through some ways to protect their legal rights, interests, and quality of life. To improve the participation is not

only EPA's goal for environmental justice, but also the research endeavor in this discussion.

A large number of empirical studies on environmental justice analysis addressed the spatial inequality in pollution based on the GIS technology (Sheppard et al. 1999; Jerrett et al. 2001; Higgs and Landford 2009; Pearce et al. 2010). Higgs and Landford's (2009) research is about estimating population influenced by landfills in Wales. They used the dasymetric mapping techniques to provide a more realistic representation of actual population distribution. Jerrett analyzed the particulate air pollution in Hamilton, Canada. Except to testify whether the environmental injustice exists in the study area, Jerrett also tried to calculate the sensitivity between socioeconomic status and levels of particulate air pollution. Pearce and his colleagues' (1999) study concentrated in the spatial inequalities in health in the United Kingdom. Sheppard compared two measures in GIS-based environmental equity assessment, and offered a methodology for evaluating the significances of these results.

Moreover, there are some environmental justice researches concerned something other than pollution. Cutts et al. (2009) investigated whether the distribution of walkable streets and parks has influence on people's healthy condition – obesity. Nega, Fu, and Vrtis (2010) designed the open space index (a GIS-based tool) for assessing human penetration of a landscape. They investigated the total amount of open space and their distribution of each county in the Twin Cities Metropolitan Region, and find out whether inequalities exist in the distribution of open space among different socioeconomic classes. Davis and Jha (2011) integrated the environmental justice research into the transportation planning. The original purpose of building highway in communities contained large population of

disadvantaged group is improving their travel facilitation, living condition and quality of life, and stimulating economic development. However, the construction would arouse the impacts on health and safety issues. Their study provided a dynamic model for improving accessibility of protected populations in transportation related projects.

Previous research addressing environmental justice has some restrictions. Most studies are the basic analysis to testify whether the pollution or land-use pattern violate the environmental justice. And their research priorities concentrate in the methodology analysis. To be more specific, Sheppard et al. (1999) illustrated the methodological issues in environmental equity analysis such as differences in data used, measures of potential exposure, study area, and geographic scales. And their research objective is to provide some standards for future environmental justice analysis, to make the results more consistent and accurate. What is more, when Mennis (2002) use census and EPA data to analysis the relationship between socioeconomic character and environmental risk in southeast Pennsylvania region, he mainly discussed about the methodology issues like modifiable areal unit problem and different methods of measuring demographic character within a given proximity of a hazardous facility. The target audiences of most researches on environmental justice are specialists and scholars or governmental agencies interested in this area. General public can hardly get information from these professional research papers, so that they cannot get well involved in the process that is closely linked with their everyday life. The history of environmental justice has been over 30 years, relative research cannot just stop in the methodology analysis. And the most important group in the environmental justice issue – general public, should be involved, no matter in data

collection or decision-making process. This paper summarized four major obstacles that prevent the further development of environmental justice.

- Top-down model

Like Sieber (2006) mentioned the first generation of PPGIS, previous study on environmental justice using GIS tools to analyze the spatial differences in distribution of hazardous facilities or amenities by mapping social and economic demographic factors. This kind of analysis is like the top-down approach. In GIS analysis process, the researchers are the executives, the decision makers. They collect data, decide the methodology, analyze the result, and give suggestions to the government – the whole process is completed by them. When governmental agencies want to make decisions, they just depend on scholars' report. All process comes from top to down, and its result inevitably becomes inadequate and biased.

- Limited information

The problem of limited information is partly due to the top-down model. Numerous research data come from government (Sheppard et al. 1999; Jerrett et al. 2001; Mennis 2002; Kim et al. 2008; Cutts et al. 2009; Higgs and Langford 2009; Nega, Fu, and Vrtis 2010; Pearce et al. 2010; Davis and Jha 2011). However, this approach of accessing data will put the research to a passive location. Researchers cannot start their study until governments publish the latest related data. Besides the time restriction, the study area also be restricted by data accessibility. Governments' information cannot cover everything, if researches only rely on this kind of data, the study area would be similar and lack of innovation.

- Lack of participation

Most previously mentioned researches are the specialists' work. Like Millner (2011) mentioned before, only rich and well-educated people concern about environmental justice issue. We facing the same situation in the research area: only specialists or scholars do some analysis about the environmental justice problem. General public, most of them do not know the existing of this issue and do not know why we need pay attention to it. Some of them do not realize they are suffering a disproportionate burden of environmental injustice, not to mention knowing how to solve this problem. However, involving public participation, especially those who are vulnerable to environmental injustice, in related decision-making process is an important part of the conception of environmental justice.

- Lack of implementation

Since most researches address methodology improvement to make analysis result more consistent and accurate, few papers mentioned what to do to improve the current situation of existing the environmental injustice or just hope that governmental agencies will make policy to improve current situation after noticing their study results. Environmental injustice has been testified existing in many places. The factual basis of environmental justice study has been almost completed. Researchers and planners should shift the focus to a more practical direction – implement study results to improve current unfair situation. In short term, the most effective way of implementation is facilitate public participation in the policy making process.

5.3 The Potential of Internet-based PPGIS in Promoting Environmental Justice

Fortunately, some merits of Internet PPGIS can help to solve those obstacles mentioned before and improve the research on environmental justice. Web PPGIS, as a burgeoning new tool, has been widely used in community participation and decision-making process (Al-Kodmany 2002; Carver et al. 2002; Casey and Pederson 2002; Ventura et al. 2002). With the previous experiences, Internet-based PPGIS can be used in environmental justice research area. The primary function of web PPGIS we used here is facilitating public participation. Here are some advantages of Internet PPGIS corresponding to previous research limitations.

- Bottom-up model

As Elwood (2006) mentioned, the purpose of bottom-up approach is to work with the public and let them learn how to operate GIS tools to produce their own contribution. When GIS technology is available to the underprivileged group, the process itself is the progress of promoting fair and justice. With the help of Internet-based PPGIS tool, people have lower socioeconomic status will get in touch with the conception of environmental justice, find out whether they bear a disproportionate of environmental pollution, whether they have the equal opportunity to access natural resources or amenities. Conversely, their responds can help professional researchers to do the further study; the outcome will be more objective.

- Ubiquitous data

Unlike the traditional top-down model, Internet-based PPGIS can get from everybody, as long as he/she publish data to the system through the Internet. With the help of mobile GIS and web server, researches can collect their own research data and their work will become more initiative. Comparing with the traditional way, data collection will become easy and less time- and money-consuming. Moreover, combined with official data, researchers and public can have a more comprehensive database. However, the veracity and reliability of public data is an accompanying research question need further study.

- Two-way communication

Through the Internet, a platform for two-way communication can be created. Like the land information system mentioned before (Ventura et al. 2002), chat rooms and the electronic town hall meeting were provided to facilitate the two-way communication between public and planners or decision makers. Traditional town hall meeting or public hearings often only allow less than 100 people to attend; yet electronic version can allow thousands of people on line at the same time. New media has the unparalleled advantages on attract audience. When public have concerns, they can ask professionals directly and get the feedback on time. Another example is the interactive map; it not only can be used to facilitate the two-way communication, but also can be used to collect data.

- Collaborative decision making

It is an essential part of achieving the goal of environmental justice is to enable disadvantaged groups, especially those who are affected by the environmental injustice impacts, to influence the making of environmental laws, regulations, and policies

(Millner, 2011). When their opinions become a part of reference material of the decision making process, the decision can really become the public decision. Only this kind of decision can arose the sense of identity among citizens.

5.4 Suggestions for Better Use of Internet-based PPGIS

In this study, to promote environmental justice, the most urgent and significant thing is to increase public awareness of this issue. Suggestions based on the SWOT analysis results are as follows.

- Simplicity – keep the strengths

Simplicity of interface and operation can reduce the requirements of users and attract more general public. Besides avoid users losing interests for complicated operation, to some extent simplicity can help reducing the risk of misoperation. To keep simplicity of the interface, firstly, concise instruction words should be used to replace those complicated professional words. Secondly, the design of interface, no matter the webpage or the mobile application, should be simple and clear. Thirdly, the instruction or tutorial is better integrates with operational pages rather than becomes an independent page or video. For example, explanation and instruction can be showed when the cursor moved to each button. To keep simplicity of the GIS function, basic GIS function like pan, zoom, search, add and delete could be provided for general users; an advanced fully functional Web GIS platform could be provided for interested or experienced users.

- Data collection and demonstration – keep the strengths

Collect and demonstrate data are the primary objectives of using Internet-based PPGIS in environmental management. The benefits of using citizens to collect data have been

stated before. To improve the enthusiasm of public participation, besides make the operational process simple and direct, projects need focus on the incentives, social media will also help in motivating users' interest as a popular participation platform – these will be discussed later in the Incentive and Collaboration sections. Results demonstration should be put in a prominent position, not only for increasing public awareness of a specific environmental issue, but also for arousing contributors' sense of achievement. Interactive map could be used to view and search the data submission results in the study area; statistic data including forms and charts could be used to better explain the results. What's more, user's personal submission statistics should be provided. For a project addressed environmental justice, the type of collected data could be the location of hazardous facilities or the necessary resources to see whether the distribution of pollution or resource is fair or not. The data collection could be proceeded on the community level – residents care about what happened near them. Unlike the Abandoned Developments only focused on the location of abandoned residential construction site and the potential pollution to water body, environmental justice project stressed more on the relationship between the distribution and residents' socio-economic status. A layer about residents' socio-economic status could be added to the interactive map by the project runners to help residents recognizing the environmental justice issue and they can do something to improve this situation.

- Data quality – improve the weaknesses

In order to improve the most obvious disadvantage of Internet-based PPGIS, to improve the data quality of citizen science, data verification process is essential. There are two types of verification process: the first one is use automatic or manual testing system to

ensure the data quality, and update the data after passing the test; the second one is post community-submitted data in real time, but label the data as confirmed after it has been verified. The first verification process will sacrifice the timeliness of data; the second process can involve citizen to participate in the verification process, but the efficiency and accuracy cannot be guaranteed. Indeed, extra cost will be generated no matter choose which verification process, but the project can cooperate with other organizations to reduce this expenditure. For instance, community organizations can organize residents to check the reliability of reports in their community; and professional organizations like research institutes, universities, and ENGOs can offer the help in double check process. Basically, to improve the input data quality from beginning is the most efficient resolution for this problem. To improve the quality of citizen-submitted data, besides design simple and clear operation system, education and training programs are helpful for citizens' better understanding of the project. For instance, a project addresses environmental justice and tries to collect hazardous facilities location data should let its citizen scientists clearly understand the definition of hazardous facilities. According to the degree of contamination, hazardous facilities could be in different levels; which level the project needs, or submit the data separately to the database, these kinds of requirements should be clearly notified to users.

- Incentive – respond to the threats

The best way to motivate public to contribute to a project is to reach a consensus with their interests or goals. When the public can feel this project is "their" project, in other words, when the ownership has been established, they will be very interested to participate since the project is closely linked to their everyday life. Environmental justice

project should make people aware the significance of the environmental justice issue – it is related to their daily life, affects their quality of life, and can be solved through their own efforts. Besides, award is always a useful incentive in management. Program can offer the monetary or honor award for the most active contributors in every year. In the meantime, fun and educational participation process will attract users. Off-line activities like educational or training programs, theme parties, and skill contest can be treated as incentives because people can meet new friends and exchange experiences in there.

- Participation equality – respond to the threats

Participation inequality primarily reflected in the preference on higher educated users for better data quality and the lack of devices in some groups. In order to solve this potential problem, projects can work with other organizations like schools, community organizations, or ENGOs to provide the training/education programs for those who need. Training/educational programs can teach the basic background and the relative knowledge of this project, and also teach participators how to use Internet-based PPGIS or other platform like mobile applications to view and submit data. Moreover, cooperate with these organizations provide the basic devices like computer with Internet access to those who need. To project involves various ethnic groups, language barriers may become another reason to cause the inequality. In this case, the platform should support other languages for ethnic groups' convenience. For instance, like an environmental justice project – a study on brown fields in the community with lower socio-economic status, has the target user groups – minority ethnic, low-income, or low-educated residents, education, language, and device supports are inevitable.

- Long-lasting investment and management – respond to the threats

Rely on the Internet-based PPGIS this platform only cannot facilitate public participation in environmental management; it needs lasting investment and management. First, to maximize the advantage of the two-way communication platform, users' questions and comments should be replied in time. Also, verification process should have a time limit, and the confirmed data should be uploaded to the interactive map as soon as possible. Projects can set up a schedule to publish the monthly/seasonal/semi-annual/annual statistic results of the data. What is more, official on-line activities such as inviting a professional for on-line chatting with users should be organized and managed by the project runners.

- Collaboration – seize the opportunities

As mentioned before, a number of activities' success needs collaboration. Firstly, project using the new tool – Internet-based PPGIS to facilitate public participation should use other traditional techniques like workshop and focus groups as a kind of off-line activities to strengthen the connection between users and this project. Secondly, social media can help making the participation process easier and more interesting. Projects can try to use the social media to submit data directly. For instance, geo-tagged photos can be submitted by Facebook, Twitter, Flicker, and other social media via the smart phone with GPS function. Social media account can be linked with the project account, and users can use social media share their findings or contributions to their own social networks. It may increase current users' sense of achievement as well as attract more users. Thirdly, cooperate with other organizations can make project run smoothly. For instance, educational/training programs and basic devices can be provided with the help of local

schools and universities; research institutes can help in data verification process; community organizations and ENGOs can organize contests, parties, and other fun activities for local residents.

VI. CONCLUSION

6.1 Summary

In the era of information, with the development of technology and the popularity of customer terminal equipment such as personal comupter, smartphone, and tablet, Internet-based communication is an inevitable development trend of data exchange. This thesis built a conceptual model to analyze the user, information, and site use of the six selected environmental programs using Internet-based PPGIS to find the strengths, weaknesses, opportunities, and threats of the current use of this tool. According to the analysis, in the cases like *eBird* and *OpenStreetMap*, user number did not have a very strong relationship with data submission number since the group of active users contributes the most. The most urgent task of using Internet-based PPGIS to attract citizen scientists is to retain the long-term and active contributors, or in other words, to transfer interested users to the long-term and active contributors. The results also showed Internet-based PPGIS is very useful in environmental program addressing a relative simple task and spanning large temporal and spatial extents. Based on the SWOT analysis result, the current condition of using Internet-based PPGIS in environmental management field could be generally understood. All the cases showed although weaknesses and threats like the data quality issue do exist, the incomparable strengths and opportunities of Internet-based PPGIS support the encouragement of this tool not only in environmental management issues but also in other social issues need general public participation in a wider range of time and space. Long-term programs like *CoCoRaHS,*

eBird, and *OpenStreetMap* have a vigor and long-lasting life, new programs also can have a promising future by carefully design and manage.

6.2 Current Limitation & Future Work

Limited to the research data, the background of users in the case study has not been clearly identified. Some programs, like *Abandoned Developments*, *OpenStreetMap*, and *What's Invasive!*, do not record users' background data. Program *eBird* collects users' personal information including age, gender, education level, occupation, company, address, and phone number. However, these data are not public. *CoCoRaHS* and *OakMapper* have presented some background data of users: the age range of participators in *CoCoRaHS*, and occupation in *OakMapper*. But these data are not in detail. This study tries to use Internet-based PPGIS to create an impartial participation environment. The background of users can reflect current public participation situation. Accurate and detailed background data cannot easily get from the second-hand data. Further study should be conducted in this field.

Since Internet-based PPGIS is a relatively new technology, and the cases of its application on environmental management issues are limited. This thesis chose six cases to study. Although selection criteria ensured the selected programs with different task and coverage to keep the diversity, both the case number and the case data cannot support a quantitative analysis. The qualitative analysis results may not be very comprehensive and accurate.

The results of this study are theoretic, they can be used as advices or guidance to establish a real project, but they may need to be tested again in the real project to see

whether it is really useful. In the future, a program, like an environmental justice program can be built on the basis of the suggestions. And the first-hand data of the program can support more detailed and accurate analysis. In general, the future of using Internet-based PPGIS in environmental management is very promising.

For environmental justice issue, besides provides equal access to disadvantaged group, for example offers training or education programs and basic devices, how to attract their attention to focus on environmental justice issue is another challenge. Disadvantaged group may face other more urgent problems like job and money issue. Environmental justice issue is a long-term problem, and it will affect people's quality of life. How to make disadvantaged group of people understand the significance of this issue and encourage them to make efforts to contribute to this issue need further study.

6.3 Contribution to Urban Planning

Although this thesis addressed the using of Internet-based PPGIS in the environmental management, the research results have contribution to the whole field of urban planning since public participation is an extremely essential and inextricable part in it. Urban planning is the work related to urban design, urban renewal, transportation planning, economic development planning, environmental and energy planning, and sustainable development (Levy 2010), it will be significant for publics to support the urban planning process. Some scholars indicated that public participation is a key component in the planning process, and planners could receive useful opinions that will benefit enduring urban plans. Goodspeed (2008) talked about public participation in the planning process in his study that public participation does not only deal with deliberate hearings, but also

seeking and facilitating public involvement in planning topics and the decision making process. Effective participation is a two-way process that includes sending information out to publics and getting their ideas, concerns and thoughts back (Godschal et al. 1994). Internet-based PPGIS provides an ideal two-way communication platform for urban planning on the spatial-related issues. Moreover, public participation can be in different levels due to public participators perceive threats or benefits to the economy, institution, and personal interests differently (Godschal et al. 1994). If people have strong interests or benefits, they are more likely to try to influence the decision making process which can lead to high involvement. Internet-based PPGIS is a great tool to spread effective information to facilitate the level of public involvement. Introduction chapter has described some traditional communication techniques to reach publics. Even these traditional communication techniques are helpful during the planning process, but it still difficult to reach a large number of publics and all of them have different kinds of weaknesses. All of these techniques have some major problems related to spending, time and bias. Internet-based PPGIS is a professional platform to reach a large number of audiences that will be helpful in the spatial-related urban planning process. With the development of new technology, people spend more time with new media and new digital developments. It's significant to engage the public in planning decisions through the new media, such as social media, mobile phone, tablets and other new technologies. Rather than designing public processes that simply aim for increased power for the public, immersive planning means a new way for the public to be engaged, to generate an ongoing sustainable dialogue with local officials, and to shape government action in a way that is informed in a meaningful way by its citizens (Gordon, Schirra, and Hollander

2011). Social networking is changing the political landscapes. Facebook, MySpace, Twitter, and YouTube allow individuals to become part of the larger political process through their personal digital products. Because online social networking and virtual reality tools allow information to spread quickly, it is possible to grow groups to thousands instead of holding a planning meeting for a few dozen people (Owyang 2008). According to Nielsen's third quarter social media report, Facebook has more than 140 million unique visitors that are nearly three times to the blogging. Twitter ranked third, which still reaching more than 23 million visitors. Another phenomenon that appeared in this report is that mobile social media are rising dramatically, which is a good gap for researchers to explore. Traditional public meetings limit the time and extent to which an individual can learn about a complex public issue (Evans-Cowley and Hollander 2010). As a result, participation through new media could be more effective than traditional communication techniques. Internet-based PPGIS can be treated as a new media, especially when it works with the social media. The new online social network will spread the notion of urban planning and public's comments and suggestions more quickly in a wider range.

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